Innovation plan for the 2020-2023 tariff period

27/09/2019

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1 Introduction

The present document is the improved version of Elia's Innovation Plan that was handed over to CREG on June 30th 2019, pursuant to article 26 §2 of the Tariff Methodology. On July 27th, CREG sent a letter to Elia in which it expresses its preliminary opinion on Elia's plan. CREG made 3 comments.

- First of all, according to CREG, the plan focused a lot on digitalization and not sufficiently on other important areas.
- Secondly, the innovation projects listed in the plan were not described with sufficient details : Criteria such as the possible applications of the projects and the added value for the community, how a project is declined in several work packages, how Elia interacts with external partners etc. must be explained more in depth.
- Thirdly, CREG considered that the structure of the document was relatively complex and that the individual objectives of each project, as well as the interdependencies of the projects are not sufficiently highlighted.

CREG informed Elia that the Innovation Plan as proposed was not sufficient to decide on the list of projects that would be submitted to the innovation incentive. In order for Elia to provide information under a format and with a degree of detail that would enable CREG to make a decision, a template was attached to CREG's letter. CREG asked Elia to submit an improved Innovation plan following the proposed framework. CREG asked Elia to send its improved plan for August 19th.

In an exchange of e-mails, Elia pointed out to CREG that a number of fields of the proposed template, while perhaps adequate in the context of subsidy for a research project, are not relevant in the framework of a selection of innovative projects subject to a financial incentive. CREG advised to use the proposed template as a guideline and to fill in the proposed fields when relevant.

Elia also indicated that given the amount of work involved by the rewriting of the plan, this was not feasible by August 19th. CREG allowed Elia to submit its improved plan by September 2Ca7th.

Given the fact that the language most commonly used in innovation-related activities is English, and that even a perfect translation into French or Dutch, instead of making understanding easier would make it more complicated, Elia opted for submitting its improved plan in English (one of the 3 languages prescribed by CREG in its recommendation).

As regards the structure of the document, the first chapter gives a definition of the phases of innovation including the level of expectation for each of them in term of quantitative KPI's.

In the second chapter, Elia's innovation strategy is set out as well as the concept of digital TSO's and the innovative programs that Elia has launched to support the vision and the strategy.

The third chapter gives the CREG an overview of all innovation programs without entering into too much detail of each project. At the end of the chapter, budgets per program as well as the corresponding incentive level are presented.

With the final section “Detailed report”, CREG can go deeper into the details of each project, organized as much as possible according to the format prescribed by CREG.

2 Context: the different phases of innovation and the related impact on project archetype

Different phases of innovation

Before entering the details of the innovation plan of Elia, it is important to distinguish the different types of innovation that are generally defined by the level of maturity.

Innovation steps can be presented in many different manners but we can overall identify 3 main phases in the adoption of a new innovation. They correspond to a different level of understanding of a technology which is also related to a decrease of the time to implementation: starting from exploration phase, following with the validation phase and ending with the pre-exploitation phase.

Figure 1 – Innovation phases

1) **The exploration phase:** In the first phase of innovation, the technology/or new process is generally not known by the company/ the industry. It requires then to build an initial understanding via a first proof of concept which is generally limited in term of time and budget.
   - The **goal** of these first tests is generally not to demonstrate a quantified business case but to show the possibilities and limitation of the technology;
   - **KPI's** will then mainly be hypothesis that needs to be validated regarding the advantages and the constraints/ limitations of the technology or the new process;
   - The **resulting implementation** time is then longer and we consider a complete implementation time between 5 and 10 years for such innovation.

2) **The validation phase:** in the validation phase, the technology or process is

known. However, there is still a need for validating the use case / client traction in order to confirm the added value or the size of the market. As a result the timing for implementation is shorter than in exploration phase.

- The **goal** of the validation phase is to verify that the advantages/ added value of the solution before starting production;
- As we are getting closer from the production phase, the **KPI's** are mixing qualitative KPI's (hypothesis to be proven before planning implementation) and quantitative (verification of the business case);
- The **implementation time** is then closer and ranging from 2 to 5 years.

3) **The pre-exploitation phase:** In this phase, the technology/ the process is known by the company and the innovation results either in the implementation of the new innovation or in an incremental improvement. This is the most common type of innovation, and generally run by the business directly.
   This can notably help to maintain a competition advantage of a company or to attack new segments/ geography:
   - In the pre-exploitation the technology and or the process are known and the business case is validated. As a result, the business is taking over with the **goal** to put in place a roll-out plan. This might lead to new adaptation to match with the reality of the business;
   - **KPI's** can now be more quantitative as the hypothesis about the technology and the business case have already been tested or are already known;
   - In this phase, the innovation is very **close to implementation** (assuming 1-2 years).

It is important to note that in the current report we consider the 3 levels of innovation relatively to the state of use and the knowledge of a TSO and more specifically the status at Elia itself. As a result some innovation can appear common in another industry/ business but being innovative for Elia.

As an example is the use of drones which is a common technology in use by the army for years. By comparison the application of drones for logistics, or even to people transport is still at an early stage.

Some technologies (like mobile phone app's, drones or new data components…) can then seem not innovative for the consumer business but still be early stage innovation for the sector of electricity transmission and electricity market organization.

To better assess the level of maturity of the different innovative projects presented in this report, we are for each of them referring to one of these 3 phases.

As requested by the CREG in the letter of July 18th, Elia tried on a best effort basis to fulfill the required section that the CREG has requested. It must then be acknowledged that depending on the phase of innovation of the project, the level of details that can be achieved will greatly vary, notably the KPI's and the implementation phase that will be less obvious in a very early exploration phase than in a pre-exploitation phase.

3 Elia strategy and program of innovation at Elia with related projects

3.1 Elia strategy

3.1.1 The 6 pillars

Elia Group is willing to be a frontrunner in the transition of the energy sector. To achieve this goal it has a strategy that accommodates the profound and rapid changes in the energy sector. At the same time, our strategy is robust and reflects our essence, so that we continue to create value for society in the future.

The strategy of Elia is then articulated around 6 main pillars:

1. **Ensure a secure, reliable and efficient grid**

Elia is preparing the system of the future, integrating high levels of renewable energy and new types of consumption in a secure way, while keeping the lights on and giving the market maximum use of our infrastructure.

2. **Deliver the transmission infrastructure of the future**

Elia develops the grid of the future that integrates increasing amounts of onshore and offshore renewable energy generation into the integrated European grid.

3. **Develop the electricity system and the market**

Elia is redesigning the market to encompass all kinds of technologies and market players, independently from the grid they are connected to, so they can fully exploit the economic benefits. We are committed to fostering a single European internal energy market.

4. **Cooperate to create value for society**

Elia continues to conduct a proactive and open dialogue to stimulate participation from our various stakeholders. We are a transparent and trusted advisor for decision makers to create value for society.

5. **Align culture with strategy**

Elia wants to implement a corporate group culture that puts safety and sustainability at the center of our activities and leverages the full potential of our talents to establish a high performing organization.

6. **Have eyes wide open for innovation**

Elia creates a culture of innovation and entrepreneurship to accelerate the energy transition. We build an ecosystem to develop the tools and methods that will enable a more digital, decentralized and sustainable energy system.

3.1.2 The digital TSO for better efficiency, flexibility and safety

Implementing this strategy is becoming always more complex in the energy sector in transition notably due to:

- the integration of decentralized;
- the reduction of centralized flexibility;
- the more and more interconnected market;
- the increasing need of interface with the DSO's;
- the multiplication of market players (e.g. new suppliers, aggregators, communities…);
- …

This increasing complexity will lead to major challenges to guarantee to the society an energy supply that is sustainable, affordable and secure, what we call the energy trilemma:.

- **Sustainable**: develop a grid and system operations that can enable integration of new renewables sources to maximize the share of green energy in the Belgian energy mix;
- **Affordable**: optimize the use of the assets and the existing flexibility to cope with the constraints of renewable energy (uncertain, intermittent and non-controllable) in order to avoid over-sizing of the grid which would result in a decrease of the welfare for the society;
- **Secure**: never make compromise on the quality of energy delivered, notably by enabling and incentivizing new flexibility means to balance the consumption and the production.

This will result in Elia activities that are more flexible, efficient while keeping a safe environment for the workers:

- **Flexible**: intermittency and uncertainty of renewables needs more and more agility on the way we act on the grid (maintenance activities planning, grid development planning…) and operate the grid (allocation and activation of ancillary services…). New technologies enabling a more scalable management of the system or to better prediction and planning of the work will then be key components of the TSO work of the future;
- **Efficient**: Aging of the assets and the need of flexibility will lead to multiply actions on the grid in parallel in the coming years. While the instability of the system will require to react faster and increase the level of automation. To be able to perform the TSO daily operations in this much more complex environment in a secure and efficient manner, many tasks will need to be automated or supported by new technologies.
- **Safe**: at any time, the race to more efficiency and flexibility should compromise the safety of Elia workers which can then be improved by replacing dangerous activities with new technologies (such as drones…) or by increasing support to the worker (such as dangerous condition detection or better risk planning…)

As briefly introduced new technologies, mainly digital, will be key success factor to solve the energy trilemma and then effectively run the 3 first pillars of Elia's strategy.

For that reason Elia is aiming to move towards the **digital TSO** where notably:

- **connected assets** are providing constant **real time data** flow that are processed to automatically adapt the asset management and system operations activities depending on constantly **updated forecast** of the system;
- **drones and robots** can support automatic inspection, collect valuable data and ultimately operate first actions on the lines or substations;
- **scalable integration** of decentralized flexible means is enabled via a real-time communication data exchange and an accurate forecast that is used to incentivize the participation of the maximum number of players to the market;
- system operations are automatically managed thanks to **artificial intelligence** overcoming the complex system optimization (in term of frequency, voltage or congestion management).

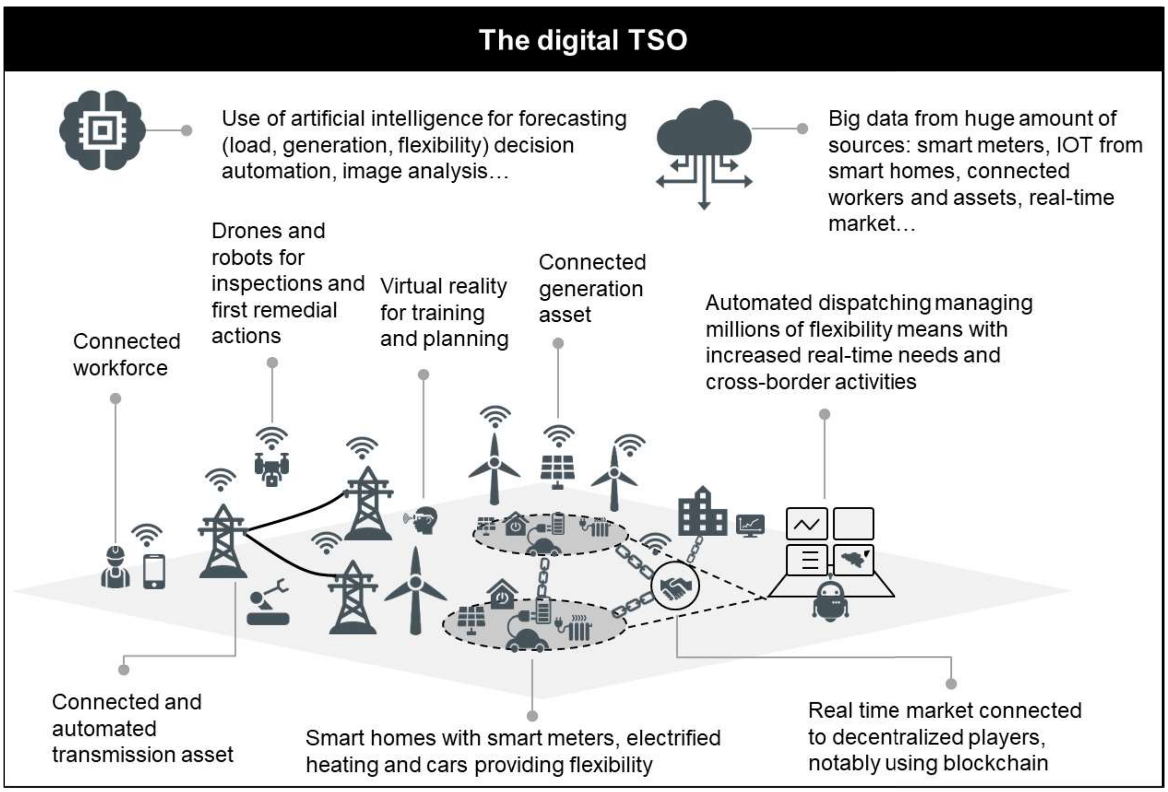


Figure 2 – The digital TSO

Among the enablers of the digital TSO, the understanding and the validation of new technologies is then key. That is why Elia is actively developing innovative initiatives aiming to accelerate the transition to the digital TSO and ultimately effectively support the paradigm shift.

3.2 Innovation program and related projects

3.2.1 Programs

In that context, Elia is developing innovation around 7 complementary programs to explore, validate and prepare for the exploitation of new technologies that will bring the efficiency and flexibility requested to solve the energy trilemma.

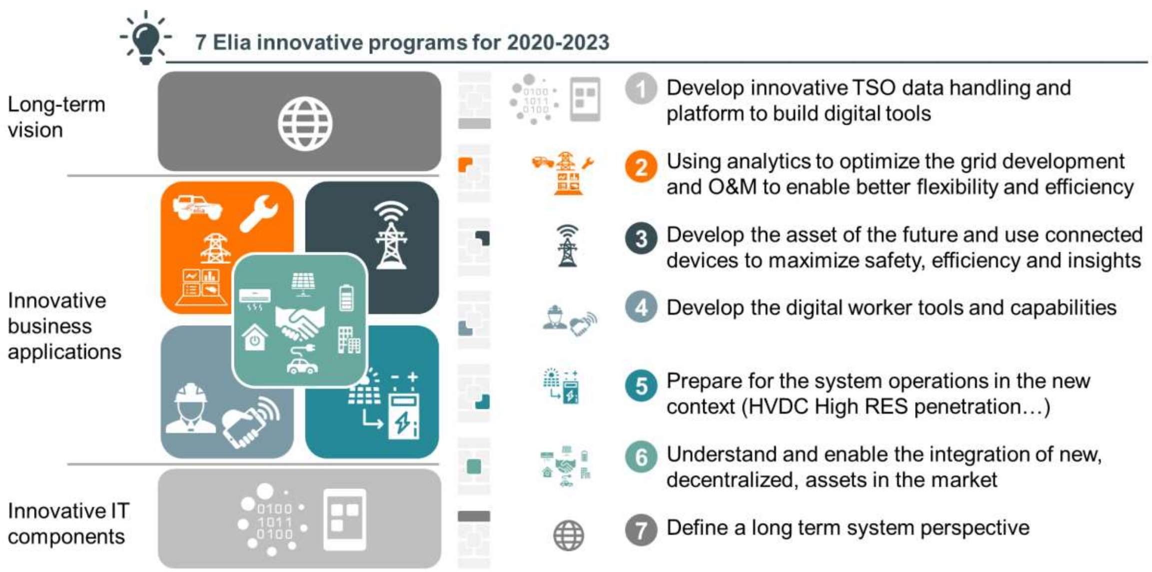


Figure 3 – 7 innovative programs of Elia for the tariff period 2020-2023

These programs are aiming to scan the full value chain from the operator on the field to the market design while also taking into account the development of innovative data and IT infrastructure.

The 7 programs are:

1 **Develop innovative TSO data handling and platform to build digital tools:**
In order to achieve the digital transformation of its business, the TSO will need to first set up a robust, flexible and innovative data/IT architecture including specific transversal platform and IT components to interface with many new applications. This should enable the connection of multiple applications and technology. Innovative components like a data lake or an integration hub will be indeed absolutely requested to unlock the potential of digital innovation leveraging new technologies like artificial intelligence, blockchain…

2 **Use analytics to optimize the grid development and O&M to enable better flexibility and efficiency:**

The increase of renewables in the energy mix will make the system operations more complex due to their inherent uncertainty and intermittency but also the resulting decentralization of the generation for which the electricity grid has not been designed initially.
These 3 elements are leading to an increasing risk for system operation each time a maintenance action is performed [redacted]. The planning of these outages becomes always more complex (notably due to the increasing number of constraints) and needs flexibility (for example due to the uncertain impact on renewables curtailment).
To solve this equation, a TSO needs to develop flexible optimization solutions to limit unforeseen outages but also minimize the down-time for regular maintenance outages including:

- Identification of assets that need to be replaced based on the quantified risk of failure and not the time
- Flexible and optimized maintenance planning creation taking into account the renewables generation, the impact on congestion and curtailment
- Efficient work preparation management and workforce assignment process
- Reduction of outage windows

3

Develop the asset of the future and use connected devices to maximize safety, efficiency and insights:

In the research for more efficiency and flexibility of maintenance and system operations activities, it is capital for the TSO to rely on data sources that are various, reliable and available in real-time. TSO's will then implement connectivity of their assets (lines, cables, towers, substations…) applying new international digital standards but also new types of sensors offering new types of insights and monitoring possibilities. The broadcasting and processing of these live data will enable more efficient detection of any equipment defect or other abnormal situations. Therefore the TSO can limit the number and duration of interventions on the grid, limiting the impact on the electricity system and market.
In parallel the use of new automatic solutions like drones and robots for inspection and eventually operations will increase the quality of detection but also drastically limit and shorten the operator's interventions on the field.
Ultimately it will also lead to safer environment by replacing human for risky operations (e.g. drones for tower inspection reducing needs of climbing…).

4

Develop the digital worker tools and capabilities:

Digitalization can play a very important role in human interactions.
It is possible to optimize the operator activities in very short time frame to cope with system uncertainty or to automate operations using connected devices to increase efficiency, but in the years to come, TSOs will still ultimately need to send operators on the field to perform grid operations.
Therefore, there are also multiple opportunities to leverage new technologies, as common as smartphone, to facilitate the job on the field, providing easily available

sources of information (e.g. digitalization of the asset information), connectivity with the rest of the company like experts or system operators.
It will also help to create better awareness for the worker about his environment using sensors to detect risky situations (e.g. magnetic fields detection using wearables sensors) or understanding of the situation using digital visualization tools.
Finally, digital technologies will also offer new training opportunities that will accelerate the onboarding process of new collaborators or to create rapidly new training programs.

5 Prepare for system operations in the new context (HVDC High RES penetration…):

Future power systems are facing new challenges when traditional thermal generation units are replaced by renewable energy sources with power electronic grid interfaces.
On one side, in central Europe, an increasing share of wind and PV generation is leading to periods with few synchronous generators in operation, and the resulting low equivalent rotating inertia in the grid can introduce stability problems. In that context, new assets like HVDC converters might play a central role in order to support the integration of power electronics devices and notably support the inertia. However, these technologies are quite new and the need of support still need to be quantified for the years to come.
As a result, an in depth analysis needs to be perform to evaluate the impact of the new class of assets and identify some proper mitigation solutions.

On the other side, variability of the system will make the everyday dispatcher work more complex; due to the increase of distributed energy resources or the increasing fluctuation and unpredictability. In parallel the new technologies are generating always more data and information that become difficult to interpret in real-time for a human being. It is then crucial to get support from new technologies as artificial intelligence and big data management tools in order to first get a proper forecast then a support to decisions and ultimately a achieve a full automation of the dispatching. This does not mean that dispatcher will no longer be needed but that the maximum of information could be processed and efficiently translated into actions under the supervision of the dispatcher. To do so, new algorithms and solutions will be developed by TSO and progressively rolled out at the dispatching.

6 Understand and enable the integration of new, decentralized, assets in the market:

The increase of renewables and the aforementioned uncertainty and intermittency is coupled with a progressive logic decrease of the role of classic centralized power plants (i.e. gas, coal, nuclear) providing currently the main share of the flexibility to manage the equilibrium between consumption and production.

Consequently we observe on one hand an increasing need of flexibility to balance the network and on the other hand, a decrease of the centralized flexibility available.

To overcome this challenge, grid operators will need to leverage more and more to decentralized flexibility which potential is increasing thanks to electrification (offering load shedding, load shifting opportunities or even power injection opportunities thanks to technology as storage or vehicle-to-grid).

From a system perspective, the prosumer's flexibility can match the increasing need for demand side management and storage integration triggered by the increasing dominance of variable RES in our electricity mix at all voltage levels and the need for more operational control to integrate them. It could also be at the basis of new business models or energy exchange such as virtual self-consumption or P2P exchanges.
However, for the moment only few market players are capable of contributing to the market and taking benefits from such set up. The consumers are still a passive component of the energy landscape and don't contribute or fully benefit from the functioning of the power system as a whole. That's why, in a near future, dynamic tariffs will be used to better steer in near real-time the consumption of connected homes and other decentralized related assets.

For TSO it is then important to understand how better interface with the decentralized flexibility players, from the contractual phase to the activation and finally the settlement.
It needs also to understand the technical and behavioral limitation and develop new solutions to forecast, incentivize and activate the new flexibility means as decentralized storage, heat pumps or EV charger considering timeframe always closer from real time to cope with the intermittency and uncertainty of the system.

As a front-runner in the TSO sector, Elia is then assessing the potential of digital innovation as artificial intelligence, blockchain or internet of energy to support this change of paradigm.

7 **Define a long term system perspective:**
In parallel of the implementation of new technologies to improve the efficiency, flexibility and safety, Elia needs to look beyond the current challenges of a TSO to prepare the long-term system operations and development.
This includes the assessment of mega international projects or the new international market design that will maximize the welfare of Belgian society.

3.2.2 Related projects

To tackle the challenges of each program, Elia has launched or will launch different projects addressing specific dimensions or important technologies of the programs.

Develop innovative TSO data handling and platform to build digital tools:

Program	Projects
1	8 Digital backbone

- The project digital backbone **(8)** is covering the development of new innovative components of the Elia digital infrastructure.

Use analytics to optimize the grid development and O&M to enable better flexibility and efficiency:

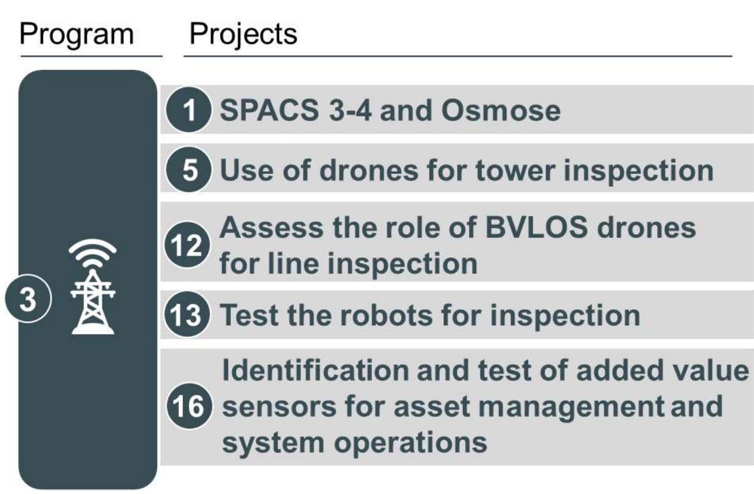
Program	Projects
2	2 Asset Control Center
	3 Optiflex
	4 Risk Based decision for grid development
	6 Use of Lidar for pruning
	15 Assessment of predictive maintenance to improve asset management efficiency
	21 Follow-up of Amex program

- To increase efficiency and flexibility of asset management, Elia is launching specific projects to cover each step of the asset maintenance value chain:
  - *Monitoring current assets*: the project Asset Control Center **(2)** aims to better identify assets close to default state. To achieve this goal, a health index representing the condition of the assets close to real time is developed to prioritize the focus of maintenance teams. The data will be based on the output of the Amex **(21)** project that is notably targeting an exhaustive collection ans treatment of assets data. In parallel of this project close to implementation, Elia is also starting exploring predictive maintenance **(15)** that will go a step further in the optimization by using artificial intelligence to predict the moment of failure of an asset;

  - *Efficiency in planning & delivering maintenance activities*: When a maintenance need is identified, Elia needs to plan the intervention which is more and more often postponed or cancelled due to variable conditions on the grid and the congestion linkedto the maintenance outage. As a result Elia is developing with the optiflex project **(3)** a new tool based notably on artificial intelligence in order to optimize the planning and make it more flexible to cope better with the system uncertainty. In parallel of the planning itself, all the preparation work (preparation of the material for the maintenance) will also be optimized to maximize the efficiency by maximizing the re-use of the operator work in case of rescheduling.

- *To prepare to a more flexible decision process:* Elia is also assessing a new way to cope with this growing number of uncertainties that grid planner is facing in decision-making processes for grid development. We are moving away from N-1 criteria that might be too or not enough conservative in some conditions towards a more risk based way. To do so, Elia has launched a project to align the appetite for risk defined at company level with the appetite for risk considered in operational grid-development and asset-management decisions (4).

Develop the asset of the future and use connected devices to maximize safety, efficiency and insights:

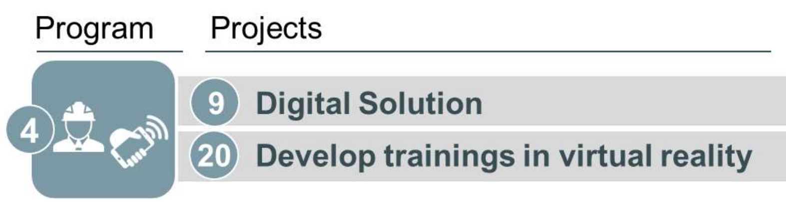


- In order to automate the process of inspection and maintenance, Elia will need:
  - to shift to a digital substation which is the role of the projects SPAC 3and 4 that also prepare for the standard IEC61850 **(1)**
  - Connect the asset: to better monitor the asset and develop more data-driven insights, Elia is launching a project to identify high added-value sensors technology and launch related test phase

(16)

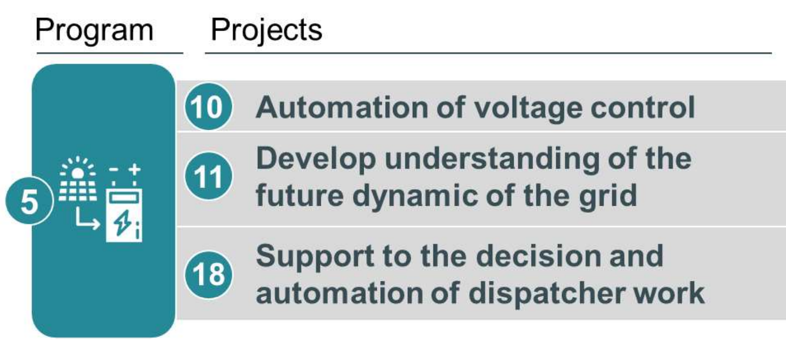
- ○ To implement the use of unmanned technology as drones, first within Visual Line Of Sight (VLOS) for tower inspection (check of rust, thermography…) **(5)**, then Beyond Visual Line Of Sight (BVLOS) for autonomous line inspection **(12)** or robots for inspection in dangerous or remote areas like offshore platforms **(13)**.

Develop the digital worker tools and capabilities:



- Elia Assets wants to create one platform solution that will be used a source for all the Assets maintenance information **(9)**. This will be used to provide information to the operator on the field, notably via smartphone application.
- Before going to field, operators have to constantly be trained as new technology, new sub-contractors, new procedures are coming every day. Elia will then test virtual reality technologies in order to facilitate the training of operators **(20)**, for example training about the dangers of working in a substation or in height (e.g. on a pylon).

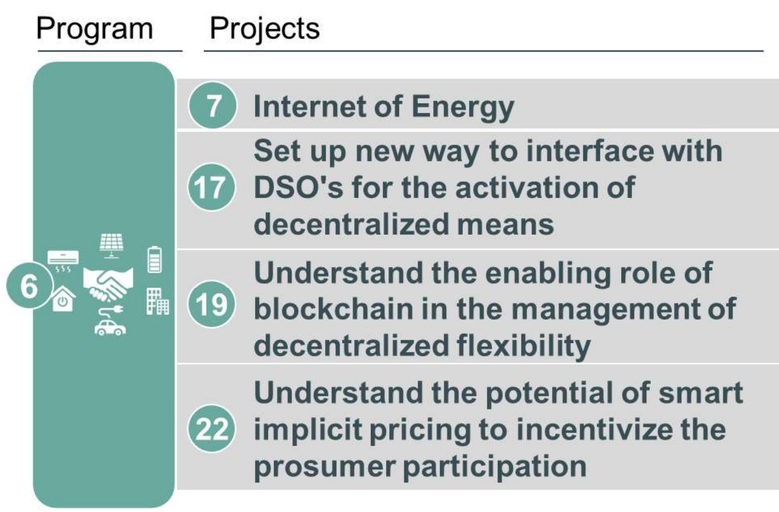
Prepare for system operations in the new context (HVDC High RES penetration…):



- Elia is actively testing the use of artificial intelligence in the different steps of the dispatcher work in order to achieve more efficient and flexible operations **(18)**: forecasting support to decision and ultimately the full automation (including activation);
- In parallel the increase of intermittency is leading to new challenges for voltage control. it is now crucial to develop and set up efficient and flexible voltage control services **(10);**
- Finally, the integration of new assets in the grid as HVDC converters,

solar inverters… might lead to new challenges for the system operations and more specifically the management of inertia. Elia is supporting different studies **(11)** to better assess what will be the impact on such an evolution on future system operations.

Understand and enable the integration of new, decentralized, assets in the market:



- As Elia needs get access to more and more decentralized flexibility to balance the grid, we are working at different levels:
  - Firstly in collaboration with DSO's Elia is setting-up the proper data infrastructure for a real-time data exchange, the IO.E. In addition Elia is also involved in breakthrough related business case **(7)**;
  - Secondly Elia is testing the potential of the different types of decentralized flexibility (notably Vehicle to grid) **(17)** and to understand how Elia operations will interface with DSO's to leverage these ones;
  - Thirdly, Elia is leading a project to develop smart pricing strategy to incentivize the decentralized flexibility to participate to the market. Indeed once the decentralized player is getting access to a market, it needs to receive the proper price level that will incentivize him to participate to the market. The goal of the project **(22)** is to use artificial intelligence to assess what will be the right price level to trigger the requested reaction.
  - Fourthly: today, certification required a specific metering and test by Elia while the financial guarantee to participate to the market [redacted] These are both important entry barriers for decentralized player to participate tot the market. Elia is then willing to understand and test how blockchain, as a trusted decentralized technology, can help to develop a more scalable solution for certification of a new players

and financial guarantee **(19).**

Define a long term system perspective:

Program	Projects
7	14 Contribution to global grid study

- With its participation in the global Grid study **(14)** Elia is studying a long term vision of an inter-continental electrical connections in order to not only gain access to high-potential remote energy resources (wind and solar) and large storage capacities (pumped-hydro), but also to compensate for the natural daily and seasonal fluctuations of renewable energy sources.

3.2.3 Project split per phase of innovation

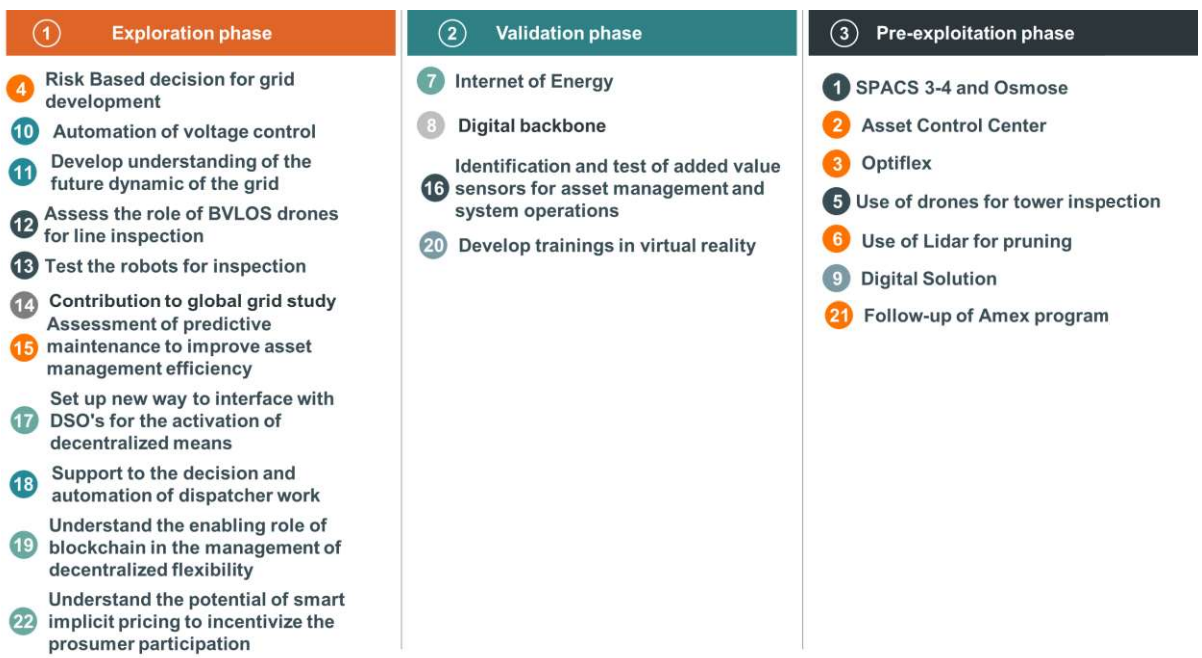


Figure 4 – Split of projects per innovation phase

As presented in figure 4, these projects cover different phases of innovation depending on Elia’s knowledge of the technology and the implementation time.

For the calculation of the incentive budget ratio of 25% is considered for pre-exploitation project and 50% for validation and exploration.

3.3 Budget per program

For each program Elia has evaluated the budget for the 4 years to come.

As described in section 2, the project in an exploration and validation phase will not necessarily lead to an implementation in the business as this decision will depend on the outcome of the exploration and validation tests.

In parallel, new technologies are continuously developed and could bring added value to the Elia business. As a result the more long term we look at the budget, the least fixed is the budget that will be allocated to innovation activities still in an exploration or validation phase today.

As a consequence, the complete budget split is available for the year 2020 while the budget is increasingly undefined as we look at 2021 and beyond. This lack of clarity in budgets represents the uncertainty of the future of an innovation, and the possible testing or validation work that might have to be performed but which is not yet in the plan currently. Therefore, we have established a floating budget evaluated based on the innovation teams and resources planning that could be allocated these activities.

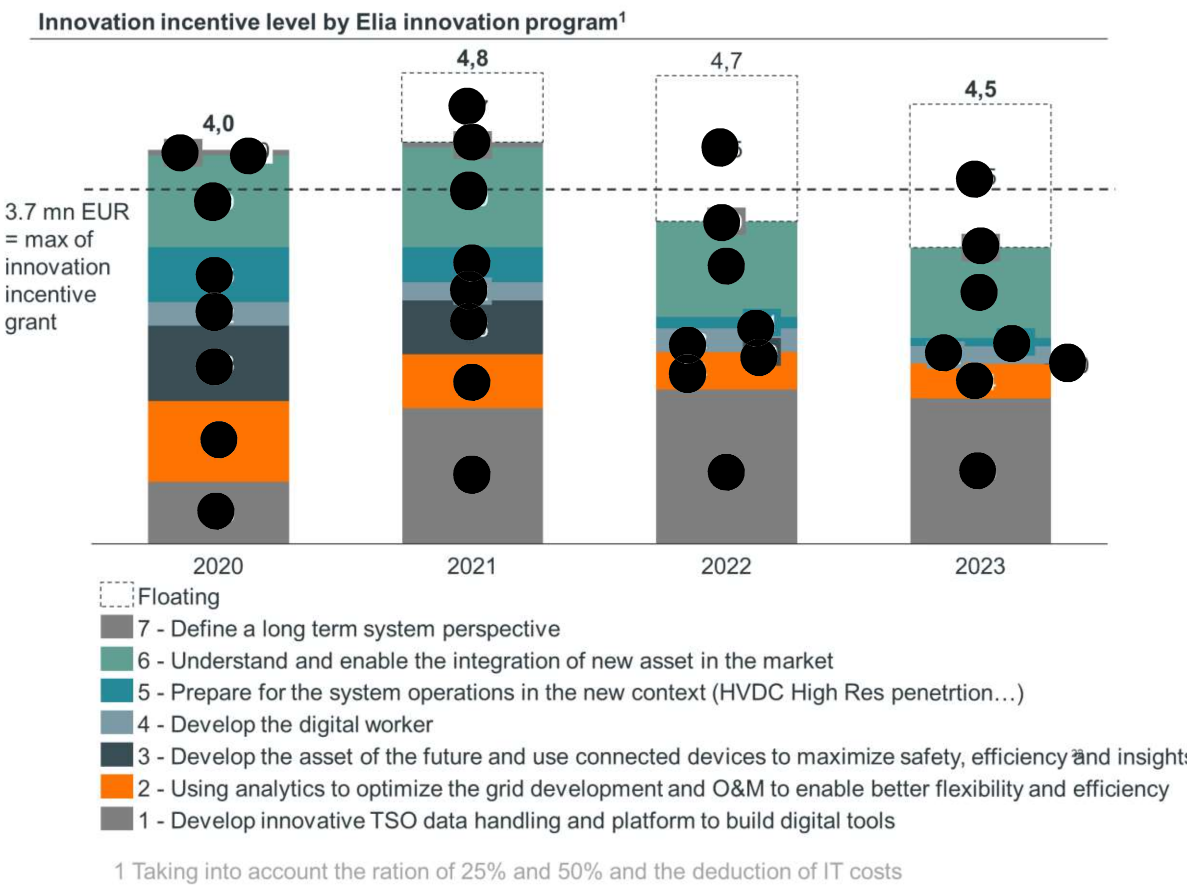


Figure 5 – Innovation incentive level by Elia innovation program

This floating budget will be progressively revised on a yearly basis and should be ultimately replaced by more fixed budget estimates.

See also the excel below for more details:

Incentive level (after application of related ratio) in mnEUR				
Program	**2020**	**2021**	**2022**	**2023**
1 - Develop innovative TSO data handling and platform to build digital tools	[redacted]	[redacted]	[redacted]	[redacted]
2 - Using analytics to optimize the grid development and O&M to enable better flexibility and efficiency	[redacted]	[redacted]	[redacted]	[redacted]
3 - Develop the asset of the future and use connected devices to maximize safety, efficiency and insights	[redacted]	[redacted]	[redacted]	[redacted]
4 - Develop the digital worker	[redacted]	[redacted]	[redacted]	[redacted]
5 - Prepare for the system operations in the new context (HVDC High Res penetrtion…)	[redacted]	[redacted]	[redacted]	[redacted]
6 - Understand and enable the integration of new asset in the market	[redacted]	[redacted]	[redacted]	[redacted]
7 - Define a long term system perspective	[redacted]	[redacted]	[redacted]	[redacted]
Floating	[redacted]	[redacted]	[redacted]	[redacted]

COMPLETE PROJECTS REPORT

STRUCTURE OF PROJECT DESCRIPTION

Introduction

As requested by CREG in its letter of July 27th, the projects description has been deepened to comply with a more detailed framework.

For each project the reporting is articulated around 4 main sections:

A. ***Innovation objective & problem to solve***
B. ***Definition of project and planning***
C. ***Context/ Stakeholders of the project***
D. ***Valorization plan***

It must be noted that, as described in section 2, the level of granularity of the KPI's and the implementation/valorization plan varies greatly between an innovation at exploration stage or pre-exploitation phase.

As a result, some project descriptions will be much more detailed than others, as in some cases, the project description cannot cover all the fields suggested by the reporting structure suggested by CREG (see answer to the innovation plan initially submitted on July 1st).

Details of the sections

As much as possible Elia has tried for every project to fulfill the following sections:

A. *Innovation objective & problem to solve*

- Problem
- General objective
- Impact for Elia : KPI's and/or hypothesis (qualitative and quantitative)

B. *Definition of project and planning*

- Overall type of the project (phase of innovation)
- Split in workpackage
- Planning per workpackage

C. *Context/ Stakeholders of the project*

- Overall type of the project (phase of innovation)
- Split in workpackage
- Planning per workpackage

D. Valorization plan

- How does the project participate to the strategic objective
- Link with the other innovative objective of Elia
- Publication
- Implementation plan
- Potential next steps

1. SPACS 3-4 AND OSMOSE

A. Innovation objective & problem to solve

Short introduction to SPACS 3 and SPACS 4

“SPACS” refers to the numerical standard bay protection cubicles deployed by Elia. Each cubicle protects the equipment connected to one bay of a given substation. Accordingly, these SPACS cubicles are connected to:

- the primary bay, in order to receive information from high-voltage equipment (currents measurements, voltage measurements, equipment positions and alarms) and in order to send tripping orders to the circuit breaker when needed (internal fault or grid operation need as a typical example);
- other secondary systems equipment of the substations, like for example the DCS (Digital Control System) aimed at sending/receiving information to/from the control centre (alarms, equipment positions, manual tripping order, etc.).

All these components can be seen in **Error! Reference source not found.**6 illustrating t he conceptual architecture of a secondary system substation as it is installed today.

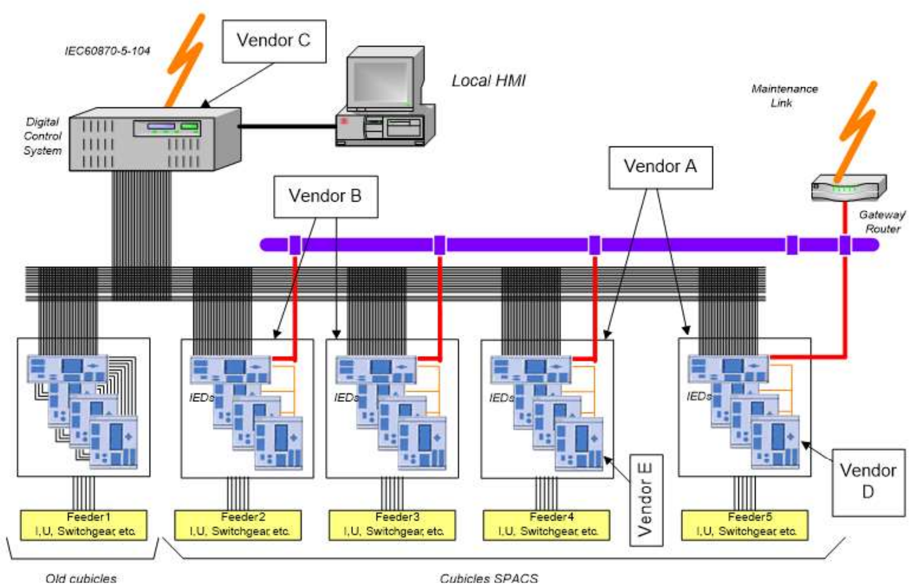


Figure 6 - Current architecture of a secondary system substation

SPACS 3 and SPACS 4 relate to the next generations of protection cubicles that will be deployed on the Elia grid. SPACS 3 is currently under development: the contract was awarded in 2018, the applicative standards are under construction in order to start the deployment from 2020. SPACS 4 will come after SPACS 3, and will implement the concept of Digital Substation. The final concept of SPACS 4 has not been defined yet, we will first test the technology through a pilot project whose development will start from

2020. **Error! Reference source not found.** summarises the main differences between t he current architecture and the following ones.

	Communication between			Functional integration
	Bay and protection cubicle	Protection cubicle and DCS	Protection cubicles	
Current SPACS cubicles	Copper wiring	Copper wiring	Copper wiring	Limited
SPACS 3	Copper wiring	IEC61850 ed 2	Copper wiring	High
SPACS 4	IEC61850 ed 2 or later	IEC61850 ed 2 or later	IEC61850 ed 2 or later	Very high

Table 1 – communication ways in SPACS 3 and 4

As can be seen, the main difference that will be introduced by SPACS 3 is the use of communication protocol to exchange information between cubicles and the DCS. SPACS 4 will go a step further by testing the exchange of information through communication protocol between the primary bay and the protection cubicle. To fix the ideas, Figure 7 shows the conceptual architecture of a SPACS 3 substation.

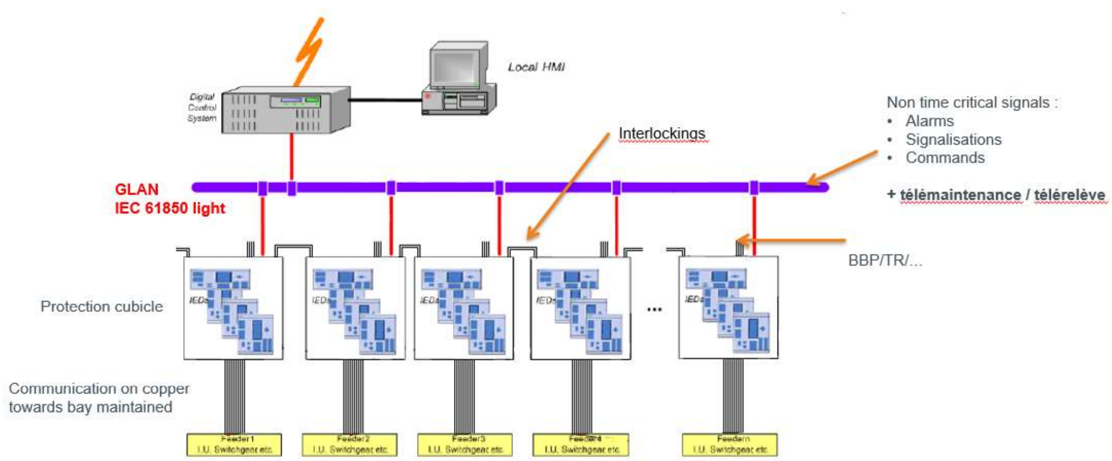


Figure 7 - Architecture of a SPACS 3 substation

The following improvements have been also foreseen for SPACS 3:

- increase the level of functional integration, in order to limit the number of relays needed to implement the Protection, Automation and Control functions;
- design the cubicle in order to be able to replace any protection relay without outage of the corresponding bay;
- facilitate the engineering tasks by simplifying as fast as possible the configuration of the relays;
- standardise the tests performed at each step of the design process (qualification, Factory Acceptance Tests, Site Acceptance Tests) in order to increase the efficiency of the supply chain.

SPACS 4 is expected to bring complimentary benefits strongly related to Digital Substation concept (to be confirmed after the pilot project):

- more flexibility in the development of advanced Protection, Automation and Control functions, resulting from the acquisition by each protection cubicle of the currents and voltages of each bay;
- full automation of the testing process due to the complete digitalisation of the relay room;
- the possibility of installing the complete secondary systems substation in containers, that can be fully tested by the manufacturers. This will strongly reduce the commissioning tests on site, and hence the outage duration for installation projects.

In order to prepare Elia to the implementation of SPAC 3 and 4, Elia is participating since Q4 2017 to Work Package 7 of the Osmose project subsidised by the European Commission in the context of H2020 tender from the EU Commission. 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. The results will help lower the cost of integration and promote a competitive environment.

In this context Elia is leading Task 1 of Work Package 7, consisting of building the demonstrators with two suppliers: Heilinks and Siemens.

Innovative nature of SPACS 3 and SPACS 4 (and Osmose)

The innovative nature of SPACS 3 is mainly a result of the following factors:

- The use of the second edition of IEC 61850, does not represent the majority of installations in the industry at the moment. The second edition of the standard was officially released in 2011, but it took several years for the manufacturers to implement this release within their equipment and to get the corresponding certificates from the official testing organisms. To illustrate this point, **Error! Reference source not found.**8 shows the time evolution of the number of manufacturers equipment who got the IEC 61850 throughout the world (source: UCA site). As can be seen, the certification has only started in 2014 (three years after standard release), and most of the equipment have been certified in 2017. It can also be observed that there is still equipment covered by certifications today (the number of certifications foreseen for 2019 is an extrapolation of the number of certifications already done at the date where the present document was written).

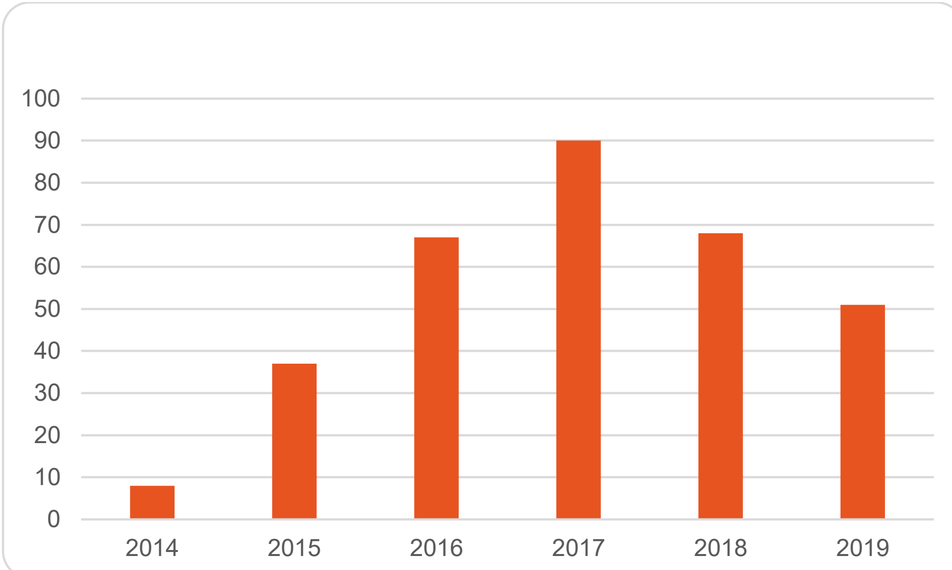


Figure 8 - Number of manufacturers equipment who got the IEC 61850

- The use of IEC 61850 solution in a multi-vendor configuration. Nowadays, most of the IEC 61850 substations that are installed come from a single vendor, mainly to prevent interoperability issues (see later in this paragraph). Due to the segregation of the Secondary Systems frame agreements within Elia (one framework agreement for RTU/DCS, 1 frame agreement for busbar protection, one framework agreement for SPACS protection cubicles), it was clear from the beginning of SPACS 3 that at least a part of the corresponding protections cubicles would have to be interfaced with DCS from other vendors. It is well known in the IEC 61850 community that interoperability issues are still existing between equipment from different vendors, even if efforts have been undertaken over the last years to solve these issues (on-going development of ENTSO-E standards aimed at guaranteeing interoperability, InterOPerability sessions (IOP) organised by UCA, etc.). However, user experience shows that a special attention still needs to be paid at that level.

- Design, commissioning and maintenance activities will be substantially impacted by the introduction of SPACS 3:

    - Business processes, tools and procedures to be used will differ from the current ones, mainly through the IT dimension introduced by SPACS 3. To give a concrete example, IEC 61850 communication test cannot be done without a protocol analyser, whereas classical copper wiring test only requires a simple voltmeter
    - Accordingly, these new business processes, tools, procedures together with the corresponding applicative standards are currently under development by expertise departments, in strong collaboration with SPACS 3 contractors. Qualification of the technical solutions is also on-

going, in order to make sure that what will be deployed has the requested level of reliability.
    - Finally, new competences will have to be developed internally by all the concerned users in the various operational departments. More concretely, we speak here about 80 to 90 people who will have to receive a well-adapted training.

The innovative character of SPACS 4 results from the introduction of Digital Substation concept, whose process bus technology (exchange of information between the bay and the protection cubicles though the IEC 61850 protocol) is one of the main parts. Up to now, there have been only a few of pilot projects performed in Europe, and no large scale deployment have started yet. Such a deployment would have also a strong impact on design, commissioning and maintenance activities.

Innovative character of Osmose is then directly linked to SPACS 3 and 4.

General objective

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:

- 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;
- limiting the impact on resources despite the growing inherent complexity of the technology used;
- restricting the power cuts required for corrective maintenance and commissioning tests;
- maintaining at least the same performance level as the solutions that are currently being used.

Impact for Elia: KPIs and/or hypothesis (qualitative and quantitative)

SPACS 3 should allow us to tackle the increased need for switching-box replacements in the years ahead (up 20 to 30%) while limiting the impact on capital expenditure (CAPEX) costs. More concretely, we expect to reach a total CAPEX cost reduction of [redacted] after implantation of SPACS 3 solutions. We propose to check the cost reduction that will be obtained with regard to the work implemented by the end of SPACS 3 Task 2 (see below).
SPACS 4: gains expected in terms of optimisation and flexibility on project rollout, costs and system availability (to be assessed in more detail based on the results of the pilot project). The only KPI we can define at the moment is the implementation of the project based on the schedule that has been defined at the moment (best estimate). The anticipated schedule for SPACS 4 is given in the "Planning by work package" section.

Use of the results

Supporting the energy transition						
Improving public acceptance						
Boosting Elia's efficiency levels						
Enhancing market design						

The introduction of new communication protocols and a complete overhaul of the design of our future switching cabinets, the costs involved in replacing and maintaining these cabinets will be optimised, particularly in terms of general equipment availability (e.g. the possibility of the acceptance phase for equipment taking place at the manufacturer's facilities rather than on site or the possibility of replacing such cabinets without having to cut the power to the relevant bay).

B. Definition of project and planning

Overall type of the project (innovation phase) and program

Validation (IEC61850) and pre-exploitation phase (SPACS 3-4)

Develop the asset of the future and use connected devices to maximize safety, efficiency and insights

Separation into work packages

Several steps are envisaged in the project:

Osmose project:

- As mentioned I the project description a prelude to SPACS 3 and 4, participation in Task 1 of the Work Package 7 of the European project H2020 Osmose. Main goal is to demonstrate the engineering process of IEC 61850 ENTSOE profile with different specifications tools and demonstrate the interoperability framework of IEC 61850 with products from different manufacturers.

SPACS 3

- Task 1: development of new business processes, tools and procedures together with the corresponding applicative standards. Technical qualification of the solution;

- Task 2: start of training of the operational crews and start of large scale deployment.

SPACS 4

- Task 1: setup of functional specifications for the pilot project, build and install the corresponding installation in a real substation in parallel on existing secondary system equipment (only for monitoring);

- Task 2: evaluation of the impact of the technology on the business processes, tools and procedures. Monitor the performance levels of the pilot installation. Decision go/no go for technology deployment.

Planning by work package

Error! Reference source not found.ble 2 gives the planning and the resources a llocation for 2020 and 2021, as estimated at the moment where the project was launched. There are a lot of uncertainties around the project evolution, the planning could have to be updated accordingly.

		2020	2021
Osmose	Task 1 of WP7 (FTE)	[redacted]	[redacted]
SPACS 3	Task 1 (FTE)	[redacted]	[redacted]
	Task 2 (FTE)	[redacted]	[redacted]
SPACS 4	Task 1 (FTE)	[redacted]	[redacted]
	Task 2 (FTE)	[redacted]	[redacted]
Total		[redacted]	[redacted]

Table 2 – Osmose, SPACS 3 and 4 resource allocation

The figure 9 shows the expected timetable for the SPACS 4 project (still to be discussed with the stakeholders).

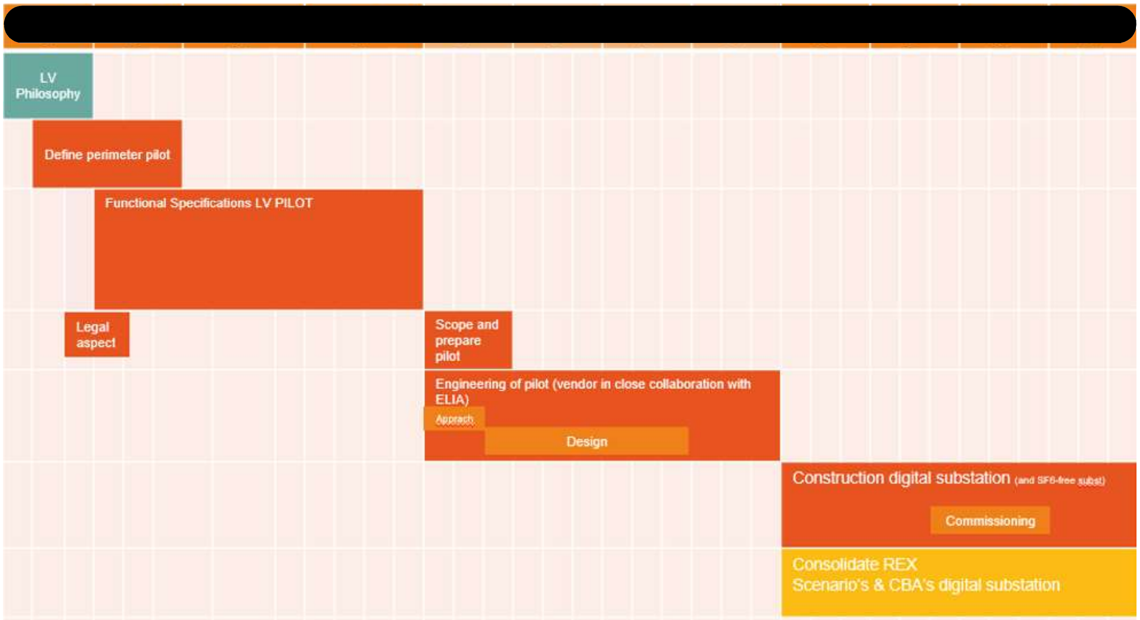


Figure 9 - Timetable for SPAC 4

C. Context/stakeholders in the project

Osmose WP 7, Task 1:

- The consortium is led by RTE and includes many different stakeholders from:
  - the network (other TSO's as REN, Terna…);
  - the manufacturers ([redacted]…);
  - Specific tools providers as IT4Power.

The suppliers for the demonstrator are Siemens and Heilinks, providing both elemen of substation for the interoperability test in a demonstrator built in Portugal (REN test substation).

SPACS 3:

- [redacted] manufacturer of a part of the SPACS 3 protection cubicles that will be installed (65%), according to the contract awarded in December 2018. The design and the qualification of the corresponding cubicles is currently on-going.

- [redacted] manufacturer of a part of the SPACS 3 protection cubicles that will be installed (35%), according to the contract awarded in December 2018. The design and the qualification of the corresponding cubicles is currently on-going.

- [redacted] manufacturer of the Digital Control System. With current solutions, the interface of this DCS with the protection cubicles is performed through copper wiring. From the moment where the first SPACS 3 cubicles will be installed, the copper wiring will have to be replaced with optical fibres, which will have impact on the design and the programming of the DCS. In some substations, the DCS could even have to communicate with recently-installed cubicles through copper wiring, and at the same time with the IEC 61850 protocol with bright new SPACS 3 cubicles. ABB is currently preparing these changes.

- [redacted] manufacturer of the equipment that will be used for the test of the SPACS 3 solution at the various steps of the process (qualification, FAT, commissioning, maintenance). They provide also support to develop the testing methodology (automation through OCC files) and to give some training to the various crews that will be impacted by the new solutions

- Cigré B5 Study Committee: we have a lot of contacts at Cigré level, in order to get experience feedbacks and recommendations from active working groups.
- Benchmark with other TSOs: we have regular exchanges with other TSOs, in order to exchange experience over current solutions deployment and to compare our vision regarding the future evolution of secondary systems substation architecture.

SPACS 4: still under discussion. We have already exchanged ideas with other TSOs about the blueprints they are planning to use and their respective experience with process bus technology (see above). There will definitely be other collaboration with third parties. Moreover, this project is being run in close cooperation with Elia's Innovation Department.

D. Value development plan

How the project contributes to the strategic objectives

As SPACS 3 and 4 are aiming to decrease the cost of the infrastructure leveraging the interoperability in the substation, the goal is in parallel to achieve more efficiency (strategic objective 1) and to deliver the infrastructure of the future (strategic objective 2)

Link with Elia's other innovation objectives

As innovation is focusing on bringing new (digital technologies) to the grid to achieve more efficiency and flexibility, the testing and final implementation of SPACS is completely in line with these first two objectives.

Publication

No publication is foreseen for the SPACS 3 and SPACS 4 projects.
While for Osmose, as a project subsidised by the European Commission, a project report will be issued for that institution.

Implementation plan

The implementation plan is presented in Figure 9.

Potential next steps

The final step is the implementation of interoperability in all Elia substations.

2. THE ASSET CONTROL CENTER

A. Innovation objective & problem to solve

Problem

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. This is described in AMEX project section (project 21).

To be able to change the focus from time based asset management to condition based asset management it is required to acquire, govern and analyse dynamic asset data in order to estimate/calculate the physical health condition of an asset (Health Index or HI).

Dynamic data of assets typically changes over time during exploitation of the asset and has an operational Asset Management use. Aside from typical measurements like Voltage and Load it also concerns indicators such as number of operations, switching time, pressure level, expert quotation during visual inspection 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 this big data is not possible in an efficient way with the available tools, which have a static referential nature.

General objective

As set out above, the overriding aim of Elia's Assets Department is to create a secure, reliable and efficient grid. The project is a software development project against the broader context of experimental development and is due to come to a close at the end of 2023.

The aim of this project is to develop an innovative software platform that will collect and store data with a view to supporting our new ambitions relating to our maintenance and replacement strategy. This means that using this platform, we will have to develop for this purpose:

- various interfaces with existing or additional monitoring devices (a very complex task because of the number and specific nature of the current devices);
- the 'health index' as a value concept for each of our main assets (this is a completely new concept for Elia and the electricity transmission and distribution sector).

In the period 2017-2019 Elia has already successfully implemented a number of asset fleets with this approach: Power Transformers, ≥70 kV (Disconnectors, Circuit Breakers, CT’s and VT’s), Underground Cables, Overhead Lines and Gas Insulated Switchgear.

For the period 2020-2023 Elia foresees:

- The implementation of this new data collection to the following fleets: Air Insulated Switchgear (AIS) ≤70 kV, Substation Buildings, Batteries 48 and 110-VDC, Shunt Reactors, Capacitor Banks, Metering Cubicles, HVDC, Low-Voltage equipment (automation, control, protection, measurement);
- The optimisation and refinement of already implemented fleets. This includes data from additional sources (IoT sensors or other data bases), but also adapting existing algorithms with our first experiences and innovating towards a predictive approach in asset management.

Impact for Elia: KPIs and/or hypothesis (qualitative and quantitative)

As the Asset Control Center (ACC) allows some maintenance work to be performed remotely, in certain cases there will be less of a need for operators to take action on site. This means a reduction in maintenance costs, but at this stage it is difficult to quantify the extent of this.

More generally, this project's impact on the company mainly comes from the AMEX levers, with the ACC serving as a catalyst for these (see above).

Use of the results

Supporting the energy transition						
Improving public acceptance						
Boosting Elia's efficiency levels						
Enhancing market design						

This project enables Elia to pass from Time Based Asset Management towards Condition Based Asset Management. Concretely this means that our employees dispose of new innovative asset information, based on data indicating the physical health of the assets.

This calculated data is available through daily reports on a fleet level and real time dashboards on an asset level, constantly updated with the latest measured data.

This will result in a better maximization of the usefulness of maintenance workforce leading to new efficiencies (not quantifiable now).Indeed it will be possible for the operator to perform different tasks remotely and spare precious time.

Our employees, but more specifically the Asset Managers, will use this new information in three cases. The first two are specifically identified as levers from the AMEX project, with a focus on efficiency, safety, security and grid availability:

1. Replacement Scoping

   The calculated Equivalent Age (EA) is the Condition Based Consumed Life expressed in years. It tells the Asset Manager whether an asset should be considered younger or older compared to its real age. The EA is an indicator of the probability of failure for the risk matrix, where 'Risk' is the product of 'Impact of failure' and 'Probability of failure'. This enables the Asset Manager to identify the assets that need a replacement the most, while other replacements can be postponed. The risk matrix (=risk taken) is aligned with the corporate strategic objectives and defined in the Asset's Fleet Replacement Strategy.

2. Maintenance Policies
The Health Index is a ratio of used physical health of an asset, calculated from wear and tear indicators, and expressed as a colour-coded %.

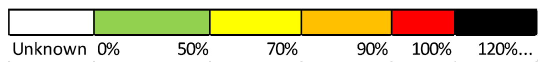


Figure 10 – Example of health indicator

0% = Health of a brand new asset; 100% = Health of the expected life is consumed; >100% = Health of the asset is technically intolerably bad compared to our defined acceptable level.
The Asset Manager uses this information to optimise their Maintenance Policy for each (sub-)fleet, by increasing or reducing the maintenance frequencies and/or by changing the type of maintenance activity.

3. Operational Activities
Aside from information to support maintenance and replacement decision making, an employee can consult the data or receive notifications for the operational follow up of assets or in his work preparation.
An example: Number of switches per day for the On Load Tap Changer (OLTC) of a transformer: when this is higher than 25 times a day, it indicates an abnormal behaviour for which an investigation on site is required. This allows Elia to avoid unnecessary wear and tear of the asset.

The result of this implementation is proven successfully and can be demonstrated with the fleet of 380kV power transformers, which was the first implemented fleet in ACC. The Health Index (HI) and Equivalent Age (EA) in this case enabled the asset manager to identify the power transformers that needed a retrofit. During a retrofit a number of components are replaced, lowering the probability of failure (e.g. bushings, ventilators, radiators). The ACC data helped the Asset Manager to know what and where he had to plan the replacement of sub-components of the transformer system. Below the HI overview before and after the retrofit project.

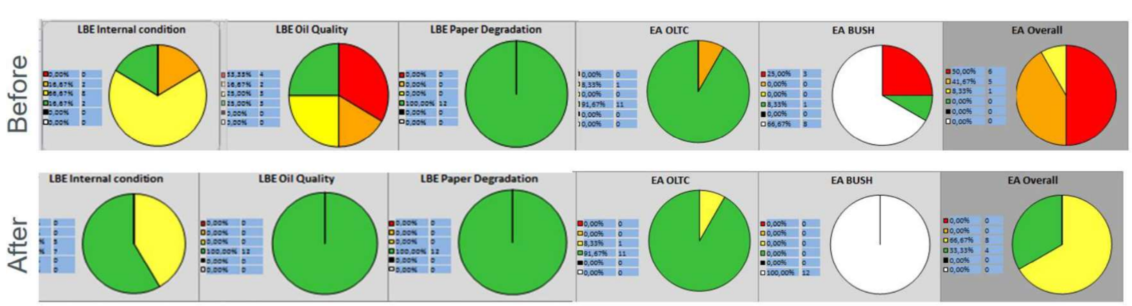


Figure 11 – Example of the Health Index Evolution

- Results of retrofits → all HI’s back in line with the corporate risk strategy.
- Impact of retrofits → saving a total of 2 assets in years of life-time! 380kV TFO’s are examples of assets which we can apply.

B. Definition of project and planning

Overall type of the project (innovation phase) and program

Pre-exploitation phase

Using analytics to optimize the grid development and O&M to enable better flexibility and efficiency

ACC started as an innovation pre-exploitation project in 2017, where the focus was on creating a platform for the processing of dynamic asset data in order to support Condition-based Asset Management. This basis had been established with an historian database, the Pi System from OsiSoft, at the core. The project scope for 2020-2023 is focused on implementing the remaining asset fleets and optimising the existing ones.

It is important to note that the innovation is more than the development of tools alone. During a proof of concept (2014-2016) we discovered that there were no Health Index algorithms available on the market for Elia’s fleet of assets. This has multiple reasons:

- Not existing (yet) at academic level (like at Cigré consortium level). In the meantime there is a publication for AIS (Air Insulated Substation) assets, but a big part is based on Elia’s experience.

- Black Box solutions from vendors, that don’t allow tweaking, don’t allow other manufacturers or don’t give the desired focus.

- Experimental algorithms from other TSO’s are only valid on their fleet with their applied maintenance policy and their asset management strategy.

Therefore we decided that we will develop our own Health Index, based on the experience of the Asset manager and the people of the field (applying FMECA or a Failure Mode, Effects Criticality Analysis) and the expertise from vendors, other TSO’s and DSO’s, and last but not least the academic world or Cigré and IEEE. This in an experimental approach that requires some iterations, but has proved to be efficient for the already implemented fleets. We also discovered that depending on the need, there are different approaches of the Health Index required. Currently we foresee three different types: 1. $HI_{Measured}$ based on the latest measurement (which can be today or two years ago) 2. $HI_{Expected}$ which is an extrapolation of $HI_{Measured}$. 3. $HI_{Weighted}$ which is used on an aggregated level of assets in order to better scope replacements (example: HI of an Overhead Line, where the black status of one isolator may not provoke a black status for the complete circuit).

Separation into work packages

ACC's implementation follows the waves of the AMEX program to identify which asset fleets benefit from Condition Based Asset Management. ACC Wave1 implemented Power Transformers, ≥70 kV (Disconnectors, Circuit Breakers, CT's and VT's). ACC Wave2 implemented Underground Cables, Overhead Lines.

Every Wave contains the tool development (reporting, interfaces with sources, data model, data cleaning…) and the definition and validation of the specific Health Index and Equivalent Age for each (sub)fleet. The operational exploitation of the HI/EA is out of the project scope and makes part of the ACC team's business as usual.

For the period 2020-2023 Elia foresees:

- The implementation of the following fleets: Air Insulated Switchgear (AIS) ≤70 kV, Substation Buildings, Batteries 48 and 110 VDC, Shunt Reactors, Capacitor Banks, Metering Cubicles, HVDC, Low Voltage equipment (automation, control, protection, measurement).
- The optimisation and refinement of already implemented fleets. This includes data from additional sources (IoT sensors or other data bases), but also adapting existing algorithms with our first experiences and innovating towards a predictive approach in asset management (see project 15).

Planning by work package

Currently ACC aims to at least have two additional implementation phases, that are linked to the results of the AMEX program. By [redacted] we aim to have developed an HI/EA for each asset that was defined in the AMEX Programme. After this, there will be additional developments for the optimisation of the current algorithms and the introduction of predictive asset management (not defined as an additional work package).

Currently <u>ACC Phase 3</u> has been defined as the next work package containing Gas Insulated Switchgear, Batteries 48 and 110 VDC, Shunt Reactors, Diesel Generators, Point On Wave switching IED, optimisation of AIS ≥70 kV and Power Transformers, introduction of a new dimension of Health index. The work package will start in [redacted]

<u>ACC Phase 4</u> will have Air Insulated Switchgear (AIS) ≤70kV, Substation Buildings, Capacitor Banks, HVDC in scope. When the results from the AMEX programme are positive, this phase might also include Metering Cubicles and Low Voltage equipment (automation, control, protection, measurement). The work package should start in [redacted] Definitive scope and planning is foreseen by [redacted] With the minimal scope in mind, Phase 4 is estimated at least at half of Phase 3,

[redacted]

C. Context/stakeholders in the project

As highlighted before, there is currently no contracted partnership ongoing.

However it is important to highlight the efforts that Elia has made before, which was investigated during the proof of concept phase.

Concept of Health Index:

- Elia performed multiple exchanges and benchmarks with different TSOs which are considered the leaders in Asset Management [redacted] None of these have the concept Health Index implemented, but are all willing to perform this type of asset management in the future.
- At Cigré level a working group has published a technical brochure on "Methodology of Asset Health Index concept" (B3.48). Elia was an active contributor for this brochure and the content is in line with ACC's implementations.

Knowing the current challenges Elia faces in terms of CAPEX and OPEX, Elia has chosen not to wait for others and started building the concept in an innovative but pragmatic way.

This does not mean that Elia isn't open for any partnerships at ACC level. Some examples of ongoing activities:

- Elia is working towards a partnership with the vendor OSIsoft that delivers the PI-System, which is the historian data base that Elia uses for its HI/EA calculations.
- Elia is experimenting with SF6 probes [redacted] to develop a predictive maintenance application. Elia is exploring the possibilities for a Master's dissertation on this subject with a technical University.
- Elia uses Online DGA monitors (Dissolved Gas Analytics) on critical power transformers and is in discussion with possible partners for improved monitors.

D. Value development plan

How the project contributes to the strategic objectives

Health Index and Equivalent Age are the only reality-based indicators for the Probability of Failure which is half of the equation for Risk-based Asset Management (Impact being the other half). It allows Elia to assess the right level of risk as defined in the fleet strategy in order to meet our objectives on safety and continuity of supply, while doing so in an optimal economic (only replace when necessary and only maintain when necessary) and digital innovative way.

Link with Elia's other innovation objectives

ACC uses data from Digital Solutions/SPACS 3-4 (1) and fuels AMEX (21) decision-making (Digital Solutions - 9) or Optiflex (3) in a later stage. Soon it will make its data available through the Digital Backbone (8) and we will test the next step with predictive maintenance (15).

Implementation plan

The implementation plan is quite straight forward.

For each asset fleet to be implemented in Phase 3 or Phase 4, we will:

- create Business Requirements based on the outcomes of the AMEX programme, including an asset specific data model, interface requirements, functional analysis and data quality verification of existing historical data;
- develop the required interfaces, analytics and reporting in test and acceptance environment (limited data set);
- deploy it in a production environment, synchronise it with all production databases and backfill historical data to update the analytics (HI/EA);
- validate the results with the asset manager;
- go to Business As Ususal with the ACC operational team.

The functional implementation to complement the earlier implementation description is detailed below.

This orange structure (DB, interfaces, analytics module, reporting) is already implemented for the assets of Wave 1 and 2. In order to implement Phases 3 and 4, the ACC project needs to adapt the existing interface, add the grey interfaces, add analytics algorithms and add asset-specific reporting.

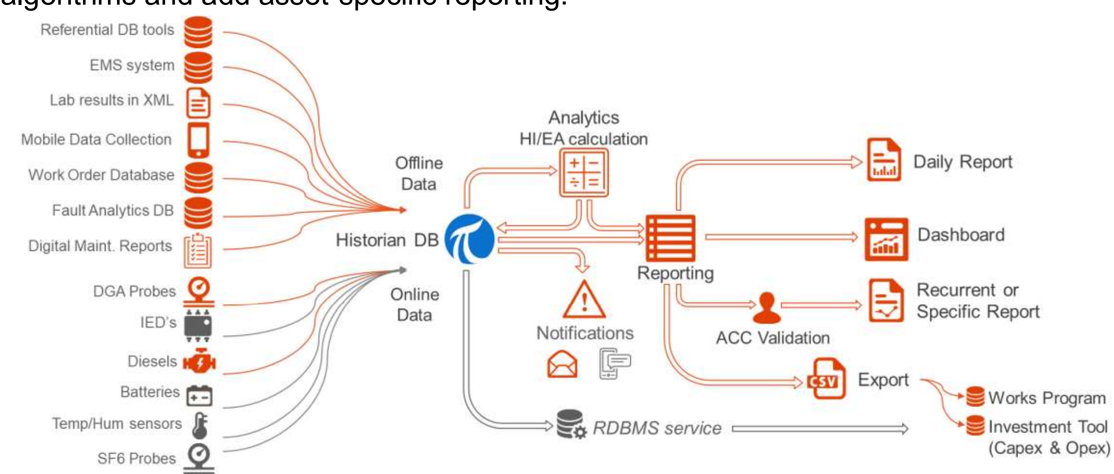


Figure 12 – ACC diagram

Potential next steps

The current focus is on condition based asset management. The next step is without a doubt predictive asset management, but it requires a solid experience, trust and even more data for ACC.

Additionally we want to explore the possibilities to use this information in more real time processes like grid operation. A use case could be that the HI will help the dispatcher in his assessment of grid reconstruction after incident (temporary overloadability when one of two parallel assets is down).

3. OPTIFLEX

A. Innovation objective & problem to solve

Problem

The challenges linked to the energy transition (increasing of intermittency and uncertainty of generation leading to challenging grid development and management), lead to more stress on our grid – some facts:

- [redacted]
- The Belgian grid was designed for a top-down flow, with central power generation at the 380kV and 150kV level. The future flow will be a mix of top-down and bottom-up and international flows with an important capacity installed at the DSO level;
- [redacted]

[redacted]

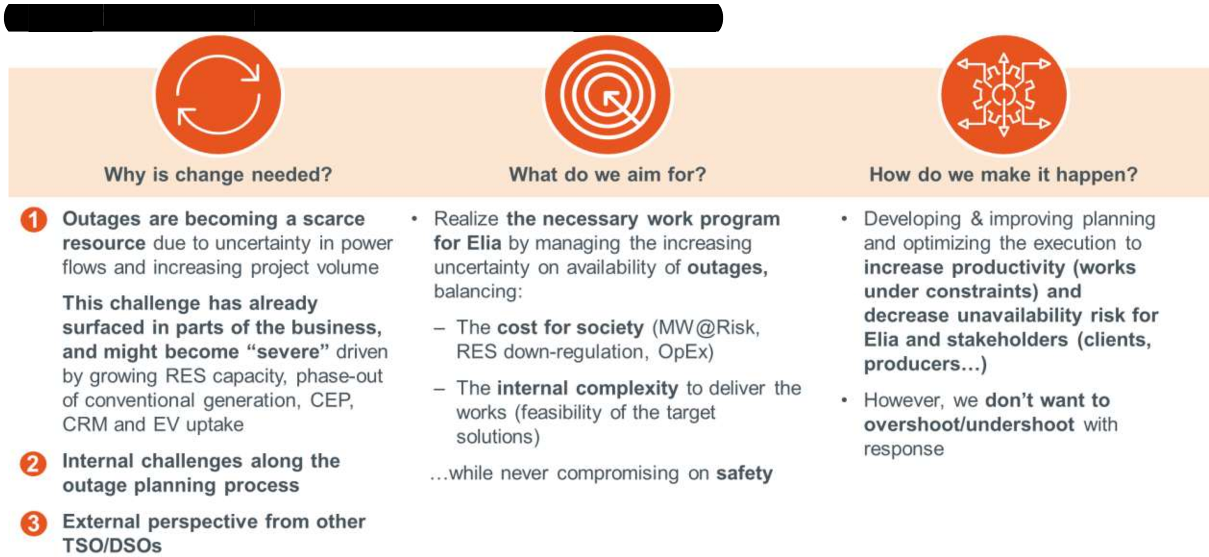


Figure 13 – Rationale behind the Optiflex project

Objective

As regards current and **upcoming** challenges, the general objectives of Optiflex are the following:

Developing and improving, through innovative solutions (e.g. using artificial intelligence), the schedule and optimising execution in order to increase productivity (works under constraints) and decrease unavailability risk for Elia and stakeholders (clients, generators, etc.).

More specifically, the programme will aim to maximise results under various constraints:
- Safety remains a first priority that cannot be jeopardised when executing our works;
- Maximising the planned Elia maintenance-work programme and implementing the validated grid project infrastructure development programme;
- Optimise the grid by planning works minimising the impact on MWh@ risk;
- Minimise RES downward regulation;
- Have the right (skilled) people on the right job and optimise travel costs and flexibility.

Here are some examples of explicit constraints to be taken into account:
- Renewables will shorten the windows of possible outages depending on sun, wind availability and the related congestion management on the grid;
- New market mechanisms will create flexibility but will also require maximum market and grid availability at critical times;
- Priorities of maintenance / capex projects will require priorities for outages on assets;
- System Assets risk management will determine priorities for maintenance and projects by assessing the condition of assets on a system wide view;
- New sourcing methods will require the right person on the right job;
- Cost efficiency like congestion costs.

Innovative character of Optiflex

Optiflex will allow Elia to face those upcoming challenges in maximising objectives under various constraints.

Therefore, Optiflex should develop innovative tools (algorithm, optimisation functions, analytical model) being able to integrate, process and maximise large volumes of data from various systems (thousands of outages and works) on a multi-annual planning for the various time frames (annual, monthly, weekly, daily) for the entire grid (380 kV up to 30 kV) taking into account all constraints (network, N-1 criteria, etc.).

Optiflex will also develop innovative solutions and processes to increase flexibility and efficiency of the work preparation and work execution.
This will include tools:
- shortening the work preparations, increasing efficiency and decreasing the planning process;
- increasing the flexibility of the work execution by constantly monitoring the execution (on a remote basis), reallocating tasks (using spare works when necessary) and maximising the time of execution (transfers between substations, etc.).

All those objectives can be realised under the condition that governance, processes and tools are developed at the same pace and in an integrated way. The digitalisation of the works is closely linked to this programme. The innovation and necessary research phase are crucial to assess, test and develop the best available tools and products to allow such large changes.

[redacted]

[redacted]

Impact for Elia: KPIs and/or hypothesis (qualitative and quantitative)

Key to the program's success will be the 'non-impact' measures despite a more complex system. In other words all the deviations from our core businesses caused by these new constraints (renewables intermittency and uncertainty and the need to constantly adapt the maintenance planning), such as the increase in decentralised renewable generation and international flows in the years ahead.

Example of KPIs that could be used to monitor the results of the programme compared with the current situation and taking into account increasing constraints:

- *Implement the annual comprehensive CAPEX and maintenance program;*
- *Minimise MWh @ Risk;*
- *Minimise # (occurrence) * MWh RES down;*
- *Increase flexibility for the workforce to better cope with the changes (# of changes vs # spare works).*

We are currently analysing a large scope of solutions and testing their efficiency following different criteria. Once the analysis has resumed, we will be able to confirm the KPIs and their concrete targets and benefits for Elia and the stakeholders.

Use of the results

Supporting the energy transition						
Improving public acceptance						
Boosting Elia's efficiency levels						
Enhancing market design						

Being able to carry out the maintenance and investment plan at minimal cost to the company (limit additional cost due to the new constraints of uncertainty and flexibility).

Developing an analytical model (using AI technology) to assess the scale and urgency of critical power cuts associated with the downward adjustment of renewable energy in the Belgian grid. Moreover, this analytical model will enable us to assess the impact of certain solution scenarios for the downward adjustment of renewable energy.

B. Project definition and planning

Overall type of the project (innovation phase) and program

Pre-exploitation phase

Using analytics to optimize the grid development and O&M to enable better flexibility and efficiency

Separation into work packages

The project is separated in five work packages that are interdependent throughout the duration of the project:

- *The definition of the function optimisation*: identification of the parameters that will impact the resolution of the planning problem and construction of the related optimisation function;
- *The planning and process*: definition of the sequence of the new planning organisation;
- *The work preparation and needs detection*: extension to the optimisation to the work preparation in order to also optimise the re-use of the preparation work done for a job that might be cancelled and achieve extra efficiency;
- *Execution and working methods*: analyse an optimized execution method for the work in order to create more flexibility;
- *Tools and data*: implement new tools and aggregate new data in order to further improve the planning and execution optimisation.

Planning by work package

Figure 14 – Optiflex planning

C. *Context/stakeholders in the project*

External partners will be involved in the development and optimisation of various AI platforms/tools with a view to streamlining the work schedule in near real time despite multiple constraints. There are not only many constraints but also a host of objectives that need to be optimised for this purpose:

- maintain a policy of zero risk to personal safety;
- implement the programme of infrastructure and maintenance projects taking into account the criticality and risk associated with the relevant projects and equipment;
- enable the optimisation of grid availability (for the market, international flows, etc.) and minimise congestion;
- minimise the impact for customers and generators (including the rapidly growing renewable generators).

To achieve this, Elia will have to call on optimisation experts, business and system analysts, and IT developers.

It will also have to look at what neighbouring TSOs are doing.

[redacted]

D. Value development plan

How the project contributes to Elia's strategic and innovation objectives

This project is improving the flexibility of the maintenance operations to cope with the increasing share of RES. To that regards, the project supports the first objective of Elia ("Ensure a secure, reliable and efficient grid").
It is also in line with the strategic objective 6 ("Have eyes wide open for innovation") as it also includes the artificial intelligence technology bringing innovation to the daily business.

Link with Elia's other innovation objectives

As described in the Risk Based Decision project (4), Optiflex is linked also to this new approach for the grid development. Indeed, the processes and methodologies identified in the Optiflex project must be taken into account in Task 2.4 in order to develop an approach to short-term grid planning that is based on explicitly setting out the risks.

Optiflex will also makeuseof the data collected in the context of the Asset Control Center (2).

Publication

No specific publication is foreseen for this project

Implementation plan

As described in the figure 14, the implementation will start in 2021 when the results of the testing will be validated.

4. RISK-BASED DECISION FOR GRID DEVELOPMENT

A. Innovation objective & problem to solve

Problem

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, including challenges in terms of operating the electricity system and integrating renewable energy and prosumers. This is mainly due to:

- the substantial market share of variable renewable generation;
- a high level of decentralisation;
- a change in consumption profiles related to sectors' electrification;
- the growing frequency and magnitude of bidirectional flows between transmission and distribution systems;
- an increased level of imports and transit flows arising from European integration.

We believe that to cope with these challenges in an effective and exemplary fashion, 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 consumers' perspective.

Objective & innovative character

To cope with this growing number of uncertainties facing the electricity system in an effective and exemplary fashion, we envisage 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 consumers' perspective.

This innovative cross-cutting Elia-internal project initial aims to align the appetite for risk defined at company level with the appetite for risk considered in operational grid-development and asset-management decisions. Objectives, grid-development criteria and asset management are devised and tailored to a more risk-based approach.

In addition, the project will help Elia develop in terms of how we plan, construct, maintain and operate the (future) grid by adopting a (more explicit) risk mentality through ensuring consistency between planning practices and operational practices. The following results are expected:

- Alignment of grid-development and asset-management policies with each other and with business strategies and risk appetite defined at company level

- Alignment of the system-operation and asset-management models by taking into account the new parameters reflecting the risks;
- New parameters reflecting the risks are included in the models used when deciding on the projects that should be prioritised. These models are based on a consistent methodology used by all the internal identifiers of grid infrastructure requirements and by defining new interfaces to connect the existing data in various tools;
- Grid planning and operating criteria updated consistently and aligned with operational objectives;
- Methods for grid development studies are tailored to highlight, several years in advance, the expected operational consequences of the long-term decisions made in each project. This is made possible by the shift in the grid analysis methods to multi-state, multi-scenario and probabilistic methods. This last method makes it possible to calculate the anticipated OPEX (including the societal costs of redispatching, load shedding, etc.) associated with a given grid-development variant. The method considers the probability of being in an N-1 situation (i.e. a situation where a grid component is unavailable due to an outage or maintenance) or even in an N-1-1 situation (i.e. a situation where one grid component is under maintenance and another is unavailable due to an outage). Therefore, decision-making can be based on taking into account both OPEX and CAPEX for the company.
- A new process and a fresh approach are put forward to align both long-term grid studies (more than three years ahead) and short term-term (from real time until three years ahead). A harmonised vision of medium-term planning would support the project decision-making process and enable a smooth transition from grid-development to operational planning activities.

Finally, the project aims to consolidate the overall risk culture within the company. It should be noted that this project makes it possible to implement part of the multi-annual strategic action plan of the CMS (Customers, Market & System) Division and the AM (Asset Management) Division.

Impact for Elia: KPIs and/or hypothesis (qualitative and quantitative)

KPIs/The keys to success are:

- the creation of an operational risk appetite that can be used in the businesses and that is in line with the company-level risk appetite;
- parameters, technical criteria and business methodologies aligned with the company-level operational risk appetite;
- improved data management with appropriate interfaces between tools;
- increased transparency between business entities, especially between decision-making in AM (Asset Management), GD (Grid Development), NetOp (Network Operation) and NCC (National Control Centre);
- increased transparency of the impact an asset's failure will have on the company;
- increased transparency of the impact that a grid-development decision will have on operational planning, asset management and future grid operation; decision-making on grid development that is based explicitly on anticipated TOTEX (including cost of redispatching, ENS, ENI, etc.) for the company;

- long-term, short-term and real-time system-management (development, planning and operating) criteria that are harmonised, transparent and aligned with the company's risk appetite;
- a consistent approach to long-, medium- and short-term inter-department planning.

Use of the results

Supporting the energy transition						
Improving public acceptance						
Boosting Elia's efficiency levels						
Enhancing market design						

The results, after validation and operational implementation in tools and processes, will be used in the following processes:

- long-term grid development studies and proposals for replacement/grid upgrading projects;
- decision-making and multi-annual prioritisation of projects in the portfolio;
- asset management in terms of maintenance and replacement needs;
- planning of power cuts for short- and medium-term maintenance and works.

B. Project definition and planning

Overall type of the project (innovation phase) and program

Exploration phase

Using analytics to optimize the grid development and O&M to enable better flexibility and efficiency

Separation into work packages

The project is separated into three work packages (WPs), each of which is divided into tasks to effectively achieve the goal:

WP 1: Align the company-level risk appetite with risk management at operational levels and decision-making based on the identification of risks.

- Task 1.1: Align the company-level risk appetite with risk management at operational levels, with a view to:

- establishing an operational risk appetite that can be used in the asset-management and system-management businesses, defining unacceptable levels of non-continuity of supply (ENS, or energy not supplied) and energy not injected (ENI), expressed in MW and for various periods;
- factoring a VoLL (Value of Lost Load) assessment for industrial and non-industrial areas into the operational risk appetite;
- comparing Elia's risk appetite with that of other TSOs.

- Task 1.2: Improve the operational risk culture. This task aims to:

  - establish a shared vocabulary and an understanding of the basic concepts of asset management and system operation;
  - develop a risk-management mentality among all internal stakeholders;
  - improve the data quality at the interface between the equipment and the system to cope with a grid that is being operated closer to its limits;
  - disseminate the results to the teams and archiving;
  - ensure the gradual migration of operational practices.

- Task 1.3: Improve long-term decisions affecting the system. This task aims to:

  - develop a 'system macro-block' concept (to design the grid based on standard grid structures defined at the outset and in which risk management between businesses is optimised);
  - identify the needs and propose a roadmap to overhaul the operational risk matrix model (including IT changes), thereby linking the system impact to the availability of grid components and assets);
  - obtain improved indicators of the importance of grid components for the system (e.g. PUT scores) to improve performance-management decisions and project decision-making (including redundancy and stability).

- Task 1.4: Improve the integration of assets in the system. This task aims to:

  - determine and establish methodologies for collecting and generating the data/statistics (e.g. regarding the unavailability of grid components) required for probabilistic grid-development studies;
  - enhance the asset-risk matrix (selectivity only);
  - enhance the quality of the asset data required for long-term planning;

- align assets' technical requirements with those of the grid components.

- Task 1.5: Improve the prioritisation rules for project portfolio management. This task aims to:

  - establish a new methodology based on existing multi-criterion prioritisation methods (benchmarks).

- Task 1.6: Define a general and consistent resilience-based approach. This task aims to:
    - define the criteria that lead to critical grid situations for which a resilience scenario must be implemented;
    - work out benchmarking with other TSOs.

WP 2: Consistent and risk-based grid planning and operation

- Task 2.1: Improve the consistency between planning and operational criteria. This task aims to:
    - further harmonise current long- and short-term and real-time criteria (stress and acceptability), in line with adjusting the business risk in WP 1;
    - coordinate regarding the use of flexibility margins between the long- and short-term system-operation phases: e.g. controllability margins (number of sockets on phase-shift transformers (PSTs), controllability of HVDC links), thermal capacity of structures (RTTR, DLR, seasonal limits);
    - coordinate regarding the expectations in terms of operational occurrence in normal, extraordinary and emergency situations (aligned with connection contracts): e.g. rare incidents, flexibility for the purpose of maintenance planning and so on;
    - enhance long- and short-term and real-time practices by observing operational risks (feedback loop);
    - further harmonising criteria and the approach in national and European long-term grid studies (e.g. the TYNDP).
- Task 2.2: Approach to and methods for long-term planning studies (Y > Y+3) consistent with the criteria. This task aims to:
    - improve the transparency of the impact of grid-development decisions on the operation and future operational management of the grid through grid-development analyses based on many expected operational points (using multi-state techniques, grouping methods and sophisticated post-processing of results);
    - assess and compare the ability to plan outages for asset maintenance on the future grid;
    - develop a model modelling the long-term market, based on the flow-based approach and aligned with the grid-development criteria;
    - develop a long-term grid-planning approach based on an explicit formulation of the risks, involving an assessment of the areal OPEX for the operation of the future grid and taking into account the probability of occurrence of an incident and the sensitivity of delays to the scenario of implementing the investment projects. This also enables certain phases of the project-implementation scenario to be defined, as well as the identification of the operational steps that will be required for future operation of the system as of the investment decisions being made.
- Task 2.3: Medium-term grid-planning method (from Y+1 to Y+3) consistent with the criteria. This task aims to:
    - adopt a planning approach that addresses both maintenance planning and adjustments to the envisaged timetable for investment projects;
    - ensure the consistent representation of market flows for medium-term planning (combining the approach developed in Task 2.2 for modelling

the long-term flow-based market and a representation based on historical market operating data).

- Task 2.4: Approach to and methods for short-term planning studies consistent with the criteria. This task aims to:
    - ensure consistency between the Y-1, M-1, D-2, D-1 and real-time studies, their criteria and the capabilities vested in the market;
    - develop a short-term grid-planning approach based on an explicit formulation of the risks, taking into account the planned timetable of outages for projects and works.

WP 3: Project management and coordination

Planning by work package

In [redacted] i.e. before the tariff period we are looking at here, the programme focused on delimiting in detail the scope of the appropriate steps and on compiling a gap analysis relating to the cross-cutting processes and the implementation of 'quick wins':

- a rough assessment of the anticipated average interruption time (AIT) based on statistical data and the system structure;
- clarification of the current policies and criteria for the long and short term and real time that govern decision-making;
- criteria updated with quick wins;
- a clear list of incidents considered in the various grid studies and impacts regarded as acceptable;
- identification of quick wins associated with changing criteria.

For [redacted] the project focuses on:

- making initial improvements to assessments of the impact on the non-continuity of supply caused by an asset failure;
- updating the risk appetite to be included in grid-development studies;
- making initial improvements to the decision-marking methodology, based on the company's risk appetite (an approach enabling internal identifiers of grid infrastructure requirements to prioritise projects consistently depending on the risk associated with failing to implement them);
- establishing a method for evaluating the maintainability of the future grid and identifying challenges for the future operation of the system that can be used with regard to the long-term grid development study.

For the [redacted] period, the improvements that can be implemented with no regret or that have a significant short-term benefit preparing Elia for the future will be the focus for the project. In particular, the goal is to achieve a transparent and consistent decision-making process aimed at:

- improving coordination between system planning and operation;
- increasing the transparency of the impact that grid-development decisions will have on operational planning, asset management and future grid operation;
- obtaining a consistent planning approach across departments in the medium term (Y+3).

From [redacted] the project will focus on the scope and testing of and planning for implementing ways to clarify the risks and on associated processes;

- increasing the consistency between studies at European, regional and national levels and the criteria;
- an explicit approach to long-term grid planning based on risk.

C. Context/stakeholders in the project

This project involves resources from 10 departments and three divisions.

Workshops with other TSOs are expected, based on an alignment of priorities. Certain TSOs, former partners in the FP7 European project GARPUR, have shown interest in further collaboration.

For certain specific project tasks, a comparative analysis with other TSOs is envisaged (e.g. alignment of the company's risk appetite).

As regards probabilistic grid planning, discussions are in progress with certain technology providers, such as grid-analysis software vendors.

D. Value development plan

How the project contributes to the strategic objectives

To cope with this growing number of uncertainties facing the electricity system in an effective and exemplary fashion, we envisage 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 consumers' perspective.

Finally, the project aims to consolidate the overall risk culture within the company. It should be noted that this project makes it possible to implement part of the multi-annual strategic action plan of the CMS (Customers, Market & System) Division and the AM (Asset Management) Division.

This all helps boost Elia's excellence in its role as Belgian transmission system operator.

Keywords: explicit risk assessment-based decision-making, probabilistic grid study, multi-criterion decision making, resilience assessment

Link with Elia's other innovation objectives

- It should be pointed that out this project and the Optiflex project are largely complementary in terms of aspects related to the preliminary assessment of the

impact that the grid-development decision will have on operational planning, asset management and future grid operation (Task 2.2). These identified changes serve as objectives for the Optiflex project;
- Moreover, the processes and methodologies identified in the Optiflex project must be taken into account in Task 2.4 in order to develop an approach to short-term grid planning that is based on explicitly setting out the risks;
- Finally, the developments in the method for analysing grid results, made in Task 2.2 (assessment of maintainability, etc.) are complementary and consistent in terms of knowledge development within Elia as regards artificial-intelligence tools applied to electricity grids, as developed as part of the 'Support of the Dispatcher using Artificial Intelligence' project (18).

Implementation plan

At the end of each project task, a set of methodologies, processes and prototype tools will be put forward. The technical specifications for the development of industrial tools, the identification of operational managers for such industrial development and an action plan for the operational implementation of the conclusions are expected at the end of the project.

The project results will be submitted for validation to the operational departments and to the committees that are normally in charge of validating the conclusions obtained by these departments. This will enable these committees to make the decision to launch the implementation plan.

It is expected that about [redacted] FTEs will be needed to monitor and roll out the implementation plan (excluding IT development). In addition, this implementation plan should be rolled out within [redacted] years of the end of each task, i.e. for the most straightforward development cases, benefits should be seen from [redacted] onwards, and for the more complex ones, rollout should be finalised in [redacted], meaning that from then on the Belgian system should operate even more dynamically than it does today (e.g. a reduction in dispatchable basic units, a rise in cross-border exchanges, increases in renewable energies and prosumers).

Potential next steps

In the longer term, multi-timeframe and multi-TSO/DSO approaches and the adoption of a modus operandi based on electricity market risks could be investigated to further increase the relevance of decisions in the company's interest and quantify the benefits from consumers' perspective.

5. USE OF VLOS DRONES FOR PYLON INSPECTION

A. Innovation objective & problem to solve

Objective

Implementation of drones within the line of sight to support field operators in their activities

Impact for Elia: KPIs and/or hypothesis (qualitative and quantitative)

Following the technological evolution of recent years, both at the level of drones and the devices that can be embedded (becoming more precise, of better quality...), and these can be considered to carry out a number of activities while allowing:

- Reduce or even completely avoid safety risks related to certain activities such as climbing up a pylon, for example;
- Reduce the execution time of certain activities such as no longer having to make cuts for an inspection of insulator chains, for example;
- Provide high quality images or measurements that can be used in different processes such as job preparation.

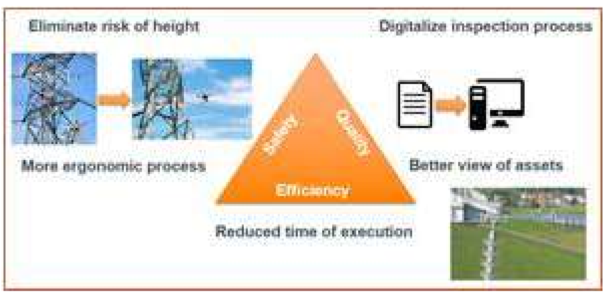


Figure 15 – Drones advantages

As we can see, it has a direct impact on various activities that are carried out within Elia, such as preparing work for repair inspections, inspecting airlines to determine their health indices, commissioning new equipment, etc.
Let us look in detail at the impacts in the context of VLOS-type inspections.

Safety

As a reminder, the law of 4 August 1996 on the well-being of workers in the performance of their work states in its chapter 5:
"Art. 5 - § 1. The employer shall take the necessary measures to promote the well-being of workers in the performance of their work. To this end, it applies the following general principles of prevention:

a. avoid risks;
b. assess risks that cannot be avoided;
c. combat risks at source;
d. replace what is dangerous with what is not or less dangerous;
e. take collective protection measures as a priority over individual protection measures;
f. limit, as far as possible, the risks in view of the state of the art;
g. limit the risk of serious injury by taking material measures as a priority over any other measure;

h. plan prevention and implement the policy concerning the well-being of workers in the performance of their work by aiming for a system approach that integrates, among other things, the following elements: technology, work organization, work living conditions, social relations and environmental factors at work;
i. provide information to the worker on the nature of his activities, the residual risks associated with them and the measures to prevent or limit these dangers:
 (1) at the time of entry into service;
 (2) whenever necessary to protect well-being;
j. give appropriate instructions to workers and establish accompanying measures to ensure reasonable compliance with these instructions;
k. provide or ensure the existence of appropriate occupational safety and health signs, when risks cannot be avoided or sufficiently limited by technical means of collective protection or by measures, methods or procedures of work organisation. »

The introduction of drone technology makes possible to act directly on the elements that are noted in bold in the article above, namely:

Cancellation of the risk of falling for certain activities such as inspecting insulator chains on a support, recording observations during major deformations of a support, etc
Indeed, these activities require mounting in the support, installing in some cases means of access in order to take pictures by an operator who sometimes has to take delicate positions.

Today, it is quite possible to consider this type of activity through drones, as shown in Figure 16, without having to mount the support with often a better quality result.

Figure 16 – Possibility to read information by doing a zoom on the picture via a desktop

- Significant reduction in the risk of falling for certain equipment replacement activities, particularly beaconing spheres and spacers in overhead lines.
  Indeed, these activities sometimes require access to the equipment via the driver. Apart from the question that arises is: "In what state is the driver in? ». By using the

drone, it is easier to check if there is no breakage of the strands and to determine the best working method and therefore access.

Figure 17 – Detection of default on a line

- Elimination of the risk of electrocution simply because these inspections can be carried out without interruptions of the overhead lines (and therefore without manoeuvres) because the drone is outside the line's safety gauge;
- However, the introduction of this new technology introduces new risks whose consequences are far less serious than the death of a man:
- Risk of the drone falling, which is compensated by people moving away from the area where the drone operate;
- Risk of collision with other aircraft, which is offset by training for all pilots within Elia, leading to a level 1A license (the most restrictive) and the introduction of procedures in accordance with the Royal Decree of 10 April 2016 on the use of unmanned aircraft in Belgian airspace.

Overall, at the level of the "Health & Safety (H)" risk matrix and for a given inspection activity, it can be said that the risk of death of a person is greatly reduced, which results in a shift from a red zone to a yellow or even green zone.

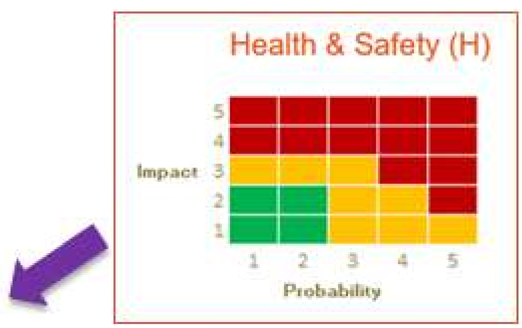


Figure 18 - Matrice de risques « Health & Safety »

Quality
In addition to the fact that the links concerned by the inspections remains in service and makes it possible to increase the reliability of supply, it should also be noted that these inspections make it possible to:
- Monitor the degradation evolution over the long term (possibility of taking the same picture several years apart);
- To better understand the state of assets by objectifying the analysis of deterioration and consequently to better calculate health indices; ([redacted])
- Better anticipate the actions to be taken on assets in order to maintain the network in an acceptable state and guarantee security of supply. This can be reflected in the

"Continuity of Supply (S)" risk matrix at the level of impact reduction as shown in Figure 19.

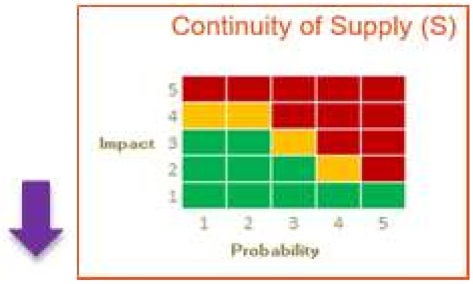


Figure 19 - Matrice « Continuity of Supply (S) »

Efficiency

Given that the inspections, which are carried out (both for substations and lines), do not require any shutdowns of the installations concerned, this leads to:

- Cancel the risk of incorrect operations at the installations concerned by the work; [redacted]

- Cancel the risk of incidents/accidents during the manoeuvre due to a problem on equipment (explosions...);

- Reduce the administrative burden in terms of work monitoring because there are no more work related cuts. However, the reader's attention should be drawn to the fact that the implementation of UAVs requires another type of work preparation (drafting of notifications to the DGLV, request for exemption for certain flights, etc.);

- Give greater flexibility in the organization of work (smoothing the workload). Working independenly of outage planning. More efficiency in

Use of the results

Supporting the energy transition						
Improving public acceptance						
Boosting Elia's efficiency levels						
Enhancing market design						

The objective of this project is to bring the innovation of VLOS drones for tower inspection from development to implementation. As a consequence, the results will be immediately of use for maintenance or asset management activities.

B. Project definition and planning

Overall type of the project (innovation phase) and program

Pre-exploitation phase

Develop the asset of the future and use connected devices to maximize safety, efficiency and insights

Separation into work packages

1. Work preparation MAC;
2. Micro view – audit of overhead lines;
3. Painting inspection (needs and work execution inspection);
4. Reduce helicopter patrol by aerial drone inspection;
5. Diagnose incident;
6. Commissioning tower;
7. Photogrammetry data capture.

Planning by work package

1. Work preparation MAC: start deployment in [redacted] continue in [redacted]
2. Micro view – audit of overhead lines: Industrialise procedure, data and tools in [redacted]
3. Painting inspection (needs and work execution inspection):Timing and scoping to be fine-tuned but foreseen in [redacted] or [redacted]
4. Reduce helicopter patrol by aerial drone inspection:
   Develop and industrialise procedure in [redacted]
   Diagnose incident, Develop and industrialise procedure in [redacted]
5. Commissioning tower: develop procedure in [redacted] industrialise in [redacted]
6. Photogrammetry data capture: Timing and scoping to be fine-tuned but foreseen in [redacted] or [redacted]

C. Context/stakeholders in the project

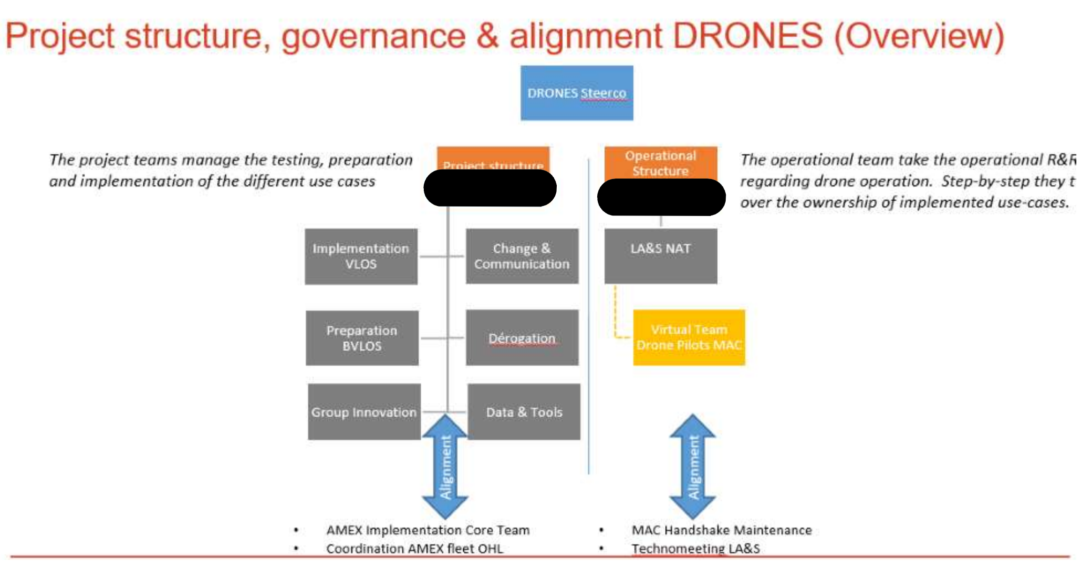


Figure 20 – VLOS drones project governance

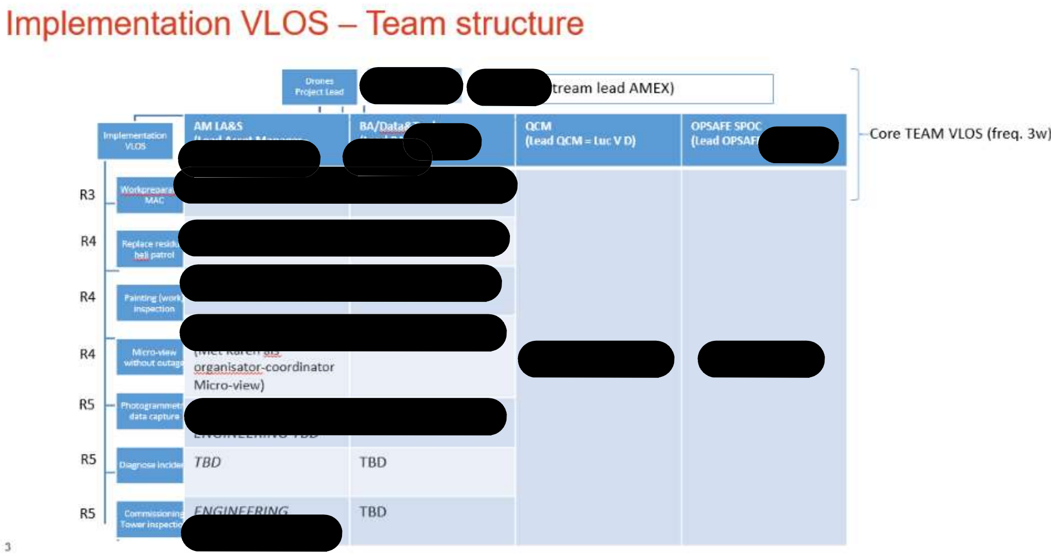


Figure 21 – VLOS drones project team structure

It would be simplistic to say that the impacts are limited to the elements mentioned above. Other elements in the organization are impacted such as:

- The working methods that will have to be adapted to include this new tool. We are thinking in particular of:
- How to respond to major incidents.
- The way to prepare the work in order to reduce the risks related to the poor knowledge of risky situations (easier detection of broken strands for example)
- How to carry out inspections such as Mirco Views for example
- …

- The computer tools that will have to be adapted in order to be able to receive the pre-analyzed information coming from a processing operation via Artificial Intelligence.

- The specifications that will have to be reviewed in order to take into account the legislative, technical and other particularities...

- The skills of the people who will need to acquire the knowledge necessary for the deployment

- …

D. Value development plan

How the project contributes to the strategic objectives

As drones will support the increase of safety for workers (less/ no needs of height work), quality (improve of defect detection rate) and efficiency (faster inspection) by deploying the use of VLOS drones in our operational practice. This new technology is a mean to achieve improvements but the know-how, processes, procedures and information management needs to be developed and integrated into the organisation in order to obtain the expected results.

Link with Elia's other innovation objectives

The innovative implementation of drones is complementary to business needs that can be found in the AMEX programme or in continuous improvement of operational activity. In that sense, close collaboration with Asset Management, QCM and Opsafe is required to align with other changes in the organisation.
Also the link with Innovation projects like SAFIR and preliminary studies on BVLOS are important to develop state-of-the-art know-how.

Implementation plan

Each work package has a plan to develop, test, validate and scale the use case within Elia.

Potential next steps

Beyond the currently planned work packages, there will be further developments opportunities for integrating drones into Elia asset operations:

- On one hand new use cases that become feasible when the market of drones becomes more mature with more niche product that can be tailor-made. (e.g. aerial labour);
- On the other hand BVLOS use cases that will become feasible when Elia has been able to progress on feasibility (EU law will be adopted in 2020-2021, enabling BVLOS operation under specific scenarios).

6. USE OF LIDAR FOR PRUNING

A. *Innovation objective & problem to solve*

Problem definition

Decrease the costs of pruning for the ELIA network while guaranteeing the grid security under all circumstances.

Objective

Elia wants to objectify the need of pruning along its high voltage lines to optimise the vegetation management process and to have a control of the risks. In order to improve and follow Elia's pruning procedure and rules, Elia would like to purchase a service which is able to model our lines to measure with accurate data the intrusions of the vegetation. Those data will able us to prioritise the pruning works.

This means we are looking for solutions for:

• accurate sag and swing and clearance analysis;

• danger vegetation analysis.

Elia requires that data must be captured by using LIDAR technology and aerial imagery (optional) but leaves it up to the tenderer to put forward a solution that meets the specific output criteria.

Impact for Elia: KPIs and/or hypothesis (qualitative and quantitative)

Reduce OPEX costs for pruning

For the first iteration the North-East zone will be surveyed (respective OPEX cost of [redacted]). Lidar survey will give an objective insight in the pruning needs and challenge the necessity and timing of pruning works.

The following estimates are made

[redacted]	[redacted]	[redacted]	[redacted]
[redacted]			
[redacted]	[redacted]	[redacted]	[redacted]

Use of the results

Supporting the energy transition						
Improving public acceptance						
Boosting Elia's efficiency levels						
Enhancing market design						

From study to implementation within Elia.

LIDAR is only impacting the inspection process of pruning. In a later stage, other applications can be further developed.

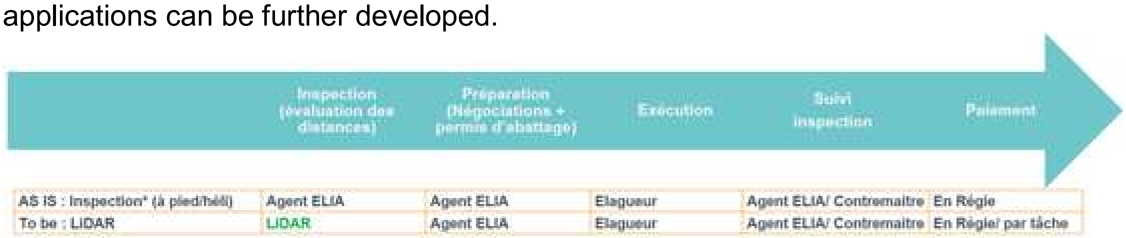


Figure 22 – Steps for Lidar project

B. Project definition and planning

Overall type of the project (innovation phase) and program

Pre-exploitation phase

Using analytics to optimize the grid development and O&M to enable better flexibility and efficiency

Separation into work packages

1. Specification of aerial survey for pruning applications
2. Product policy + tender + survey
3. Process and reporting development
4. Training and Setup organisation
5. Benchmarking with 'as is' process to validate assumptions
6. Repeat survey cycle with optimised scope

Planning by work package

1. Specification of aerial survey for pruning applications
2. Product policy + tender
3. Process and reporting development
4. Training and Setup organisation
5. Benchmarking with 'as is' process to validate assumptions
6. Repeat survey cycle with optimised scope

C. Context/stakeholders in the project

AM for the inspection policy and specifications
QCM (Quality, Competences and Methods)for the work methods
Purchasing to purchase the service effectively perform LIDAR scanning flights
MAC (Maintenance Asset and Commissioning) incorporate the data and reports in their day to day decision process
Vansteelandt will perform the flight and bring the LIDAR technology.

D. Value development plan

How the project contributes to the strategic objectives

Reduce OPEX costs for pruning

Link with Elia's other innovation objectives

The project is being monitored with the governance of the AMEX programme.

Implementation plan

Given the specific expertise of lidar sensors, a service will be contracted to perform the aerial survey. A project team is set up to implement and develop internally the know-how to work with the results.

Potential next steps

Scale up to other regions then North-East

Capitalise on the LIDAR data for other applications in Elia (contact centre, engineering projects, asset data management, etc.)

7. INTERNET OF ENERGY

A. Innovation objective & problem to solve

Problem

Today power system and market operations are still mainly centralised. Only few actors, i.e. market parties, are capable of contributing and taking benefits from such a set up. The consumers are, in such paradigm, a passive component of the energy landscape and don't contribute or fully benefit from the functioning of the power system as a whole

Over the recent years, the energy transition has shaken this paradigm. When it comes to electricity, increasing deployment of variable RES this transition, more decentralised production and further electrification are the three core components driving the evolution of the world we know today.

Last but not least, one of the important drivers for change in the sector is the societal ambition to put "the consumer at the centre" of the energy system. As stressed by the European Commission in its communication "Clean Energy for all Europeans", Europe sees consumers as active and central players on the energy markets of the future so they can fully benefit from the energy transition. The end consumers are thus envisioned, and should become, one of the key actors in this transition as they evolve towards prosumers, making value from their energy data & flexibility through so called energy services.

From a system perspective, the prosumer's flexibility can match the increasing need for demand side management and storage integration triggered by the increasing dominance of variable RES in our electricity mix at all voltage levels and the need for more operational control to integrate them. It could also be at the basis of new business models or energy exchange such as virtual self-consumption or P2P exchanges.

However, most of these new services or business models are still at the state of concept or are performed in isolation and lead to not scalable proof of concepts. Consumers on the other hand, do not look at electricity, or energy, but what they get from it. The final aim is to heat their house, cook, drive the car from A to B, definitively not to capitalise on their flexibility or their energy data.

Furthermore, the current market design is not putting the consumer at the heart of the market. There is indeed no incentive for decentralized players to participate to the market or to provide peers services as you see in some other sectors like mobility.

This leads to a status quo not offering the necessary foundation to create a truly integrated energy system focusing on consumers' needs. We don't have then a level playing field for new actors to develop novel offering for their customers and finally an to tap the potential of new flexibility means from decentralised assets (electric vehicles, batteries, smart boilers) for efficient power system operation.

This situation calls for a new approach to interact between the market payers in order to develop new energy services directly with the consumers and to avoid slow non scalable process based on an upgrade of the current market and operational practices.

To achieve this fostering of commercial and regulated interactions between consumers, markets actors and system operators, a novel perspective on data exchange must be taken. A perspective embedding the current and future technology capabilities brought by the wide use of internet, the progressive adoption of IoT concepts and finally the availability of software developments tools.

Objective

In this context, the Belgian (transmission and distribution) system operators have launched a common innovation project named IO.Energy (for Internet of Energy). This project aims at facilitating the creation and development of energy services by market actors and derive from that the necessary evolution of business processes within system operators to enable such services if their value and acceptance for consumers is progressively proven.

In other words the objective is to anticipate future required evolutions of market and system processes by, from the start, facilitating, their test and demonstration with market parties and consumers. This must take into account the little interest and awareness of consumers for system related issues and should derive to a seeming less experience for them.

Ultimately, the final ambition of IO.E is to give the opportunity to every consumer in Belgium to get access to a vast variety of energy services (ranging from monitoring, to home energy management, to access to dynamic pricing, to participation in balancing services, or benchmarking capabilities and possibly P2P exchange or participation Citizen energy communities) within the normal operational limits at all voltage levels. Elia System Operator and the other Belgian system operators are not ambitioning to perform activities in this field but to develop the necessary regulated processes to allow these applications (ex: dynamic pre-qualification of small flexible provider).

These processes will result into sub-projects using the facilities provided by IO.E. These sub-projects, called 'use cases', are either led or coordinated by Elia. The ones currently ongoing are:

- Flexity looking at novel settlement and validation processes for small flexibility assets;
- Checkmyflex looking at value and automated reaction to dynamic pricing for end consumers.

Other use cases are also performed by market third parties either with or without the direct support of Elia.

Approach

One key element to put the consumer at the centre of an energy system, is then to have access to support decision tools, automation in combination with the capability to exchange information & services almost “in real time” to match the needs either of the consumer itself, the market parties or the power system at all voltage levels.

The other key element is to facilitate a co-development process with all relevant actors from the consumers themselves, to the market actors (not only from the energy sector), the system operators and last but not least the regulators.

Most of these elements have to be created from scratch, and besides some scientific papers and scattered proof of concepts, there are currently no concrete, existing proof or even detailed design of such concept that could become available for all consumers.

Rather than tackling the above using existing tools and project methodologies currently used by system operators, the IO.Energy project is by design based on state of the art technologies and methodologies used in fast moving sectors: An open innovation methodology & a novel approach to energy data management.

An **open innovation methodology** aiming at gathering all relevant actors in an **ecosystem** to co-develop most viable products for the possible future energy services to which the consumers will have access to. Besides the coordination and facilitation by neutral entities (system operators), this methodology is also following state of the art practices in terms of innovative product and services development, such as:

- **Design thinking:** Development directly with the users or customers to integrate from the start its feedback and need to make the solution evolve from a most viable product to an offer which can be widely adopted (scalable)
- **Agile/Lean:** Development of solutions in cycles rather by phases. The product or service is developed in iteration of Build – Test – Learn activities to spot early on necessary evolutions or cancelation of features based on the learning of the precedent cycle. This methodology avoids unnecessary developments and project stops compared with a classical design, initiate-realise approach (design from the start) and has been shown to more effective in uncertain environment.

In order to support the development and test forward looking energy services, Elia and the grid operators have developed a prototype of an open real-time communication platform to ensure secure point to point data exchange among consumers, market parties and system operators. On the first hand it allows the participating consumers to share their energy consumption in real time to any parties to whom he has consented to give access. On the other hand, an authorised energy service provider can connect its first version of application and, if it has received the consent from the customer, get access to its real time consumption and send back to the identified consumer a signal: which can be of many natures (prices, traffic lights, set points, etc.). A schematic of the platform functionalities is described in figure 23:

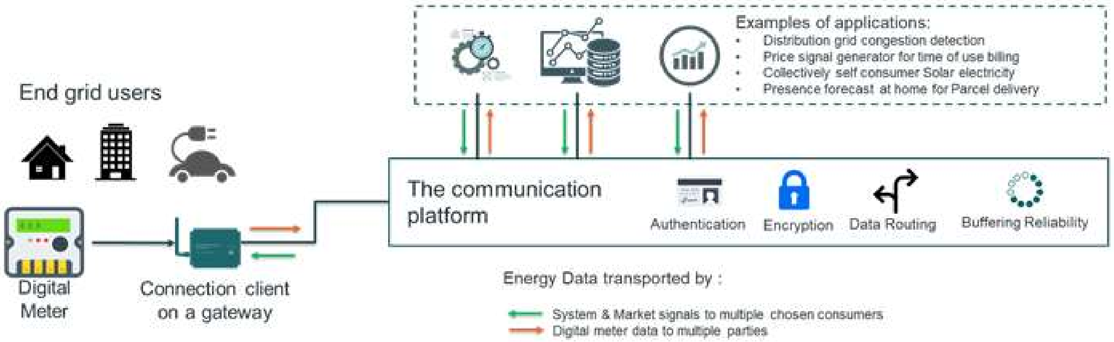


Figure 23 – Internet of Energy diagram

The theoretical architecture of the platform aims at ensuring unique features in the energy landscape:

- Enables new business models by ensuring real time data exchange and exposing power system needs;
- Creates a data level playing field by routing the data from 1 to many;
- Ensures trust among parties through grid user authentication and secured apps;
- Gives full data ownership to consumers by providing control and transparency to users;
- Keeps the privacy of interactions through protection and the absence of data storage;
- Neutral and cost effective for Belgian society by being unique, minimalistic and driven by regulated players.

While the prototype is far from providing all this features at this stage, it is progressively developed based on the feedback of the first grid users and energy services providers through the test conducted with them. This feed-back loop ensures that development resources and cost are dedicated to the value creation features.

As the final design is not known (it will depend on the progressive leanings conducted during the tests with customers), it is highly uncertain if and how these features could be ultimately delivered. Furthermore, the communication platform is built from the start on cloud based technologies which should ensure replicability, scalability and flexibility in its usage. So far, energy actors (including system operators) have relied only on operational technologies and on premises applications to perform their core activities. Using dedicated communication channels (e.g. dedicated optic fibre) and private servers are however not suited cost- and capability wise to market and system activities involving millions of active points such as active consumers.

This is a completely new technological domain for the energy sector when it comes to market and system operation exchange. Besides the high uncertainty on the future design of the platform, key questions exist regarding the relation between cyber security and the proper functioning of the power system.

In addition of the primary objective to enable consumers to get access to new energy services (using real time data exchange capabilities), IO.Energy is also a perfect test for Elia and the other Belgian system operators to analyse to what extent cloud-based technologies and their inherent advantages could be used in the future for core activities without hampering the normal operation.

Impact for Elia: KPIs and/or hypothesis (qualitative and quantitative)

As an enabler of new services access for consumers, IO.Energy in its core – the open innovation methodology and the communication platform – does not create impact which can be easily quantified for Elia. However, KPIs have been defined to measure the progressive evolution of the development towards a first target defined at the end of [redacted]

- number of Minimum Viable Products (first versions of energy services) successfully demonstrated in the testing (sandboxing) phase;
- number of industrial applications being successfully developed;
- number of grid users having access to the platform.

As said, this project aims at anticipating further necessary developments of Elia (objective shared with by and with other system operators) when it comes to facilitating market access and enable the development of new service offering. For example, the first technical lessons learnt related to communicating with decentralised assets have been used to support the redesign of the aFRR product to open it to non-CIPU units. Giving access to the aFRR product to more providers thanks to technology development resulting from IO.E testing is a first concrete quantitative impact of IO.Energy knowledge generation for Elia activities.

This was a first concrete Impact of IO.E on current activities of Elia. It is foreseen that the same “reflections” will also be posed for other balancing products (enabling a cost effective process for data gathering for settlement processes) especially regarding the interaction with DSOs practices when it comes to flexibility provision from distributed units.

Use of the results

Supporting the energy transition						
Improving public acceptance						
Boosting Elia's efficiency levels						
Enhancing market design						

On top of the technology lessons learned, the new capabilities enabled by the IO.E project (open innovation & Real time data exchange) are and will be used by Elia to find partners and test directly with real consumers key questions it has regarding the evolution of its flexibility products as well as the possible and future contribution of energy consumer into the functioning of the balancing products first, but also how its flexibility could be capitalised on, including in other market time frames.

IO.E is for Elia an open test bed to put in practice some of its innovative reflections into practice to understand if it feasible and scalable.

B. *Project definition and planning*

Overall type of the project (innovation phase) and program

Validation phase

Understand and enable the integration of new, decentralized, assets in the market

The IO.E project should be considered a non-classical approach to innovation avoiding the traps which could occur in a more classical approach. Rather than passing through classical phases from lab to prototype and prototype to testing, IO.E’s methodology relies on the overall idea “start small, fail fast”. Rather than having long development cycles before real-life testing, IO.E methodologies force the participants, including Elia to directly test with consumers the minimalistic version of the service or the product.

Such approach cannot be categorised using for instance technology readiness level, but rather look at batches of build-test-learn cycles organised over a short period to improve “live” the service.

These batches within IO.E have been defined following different maturity steps for a specific Energy services:

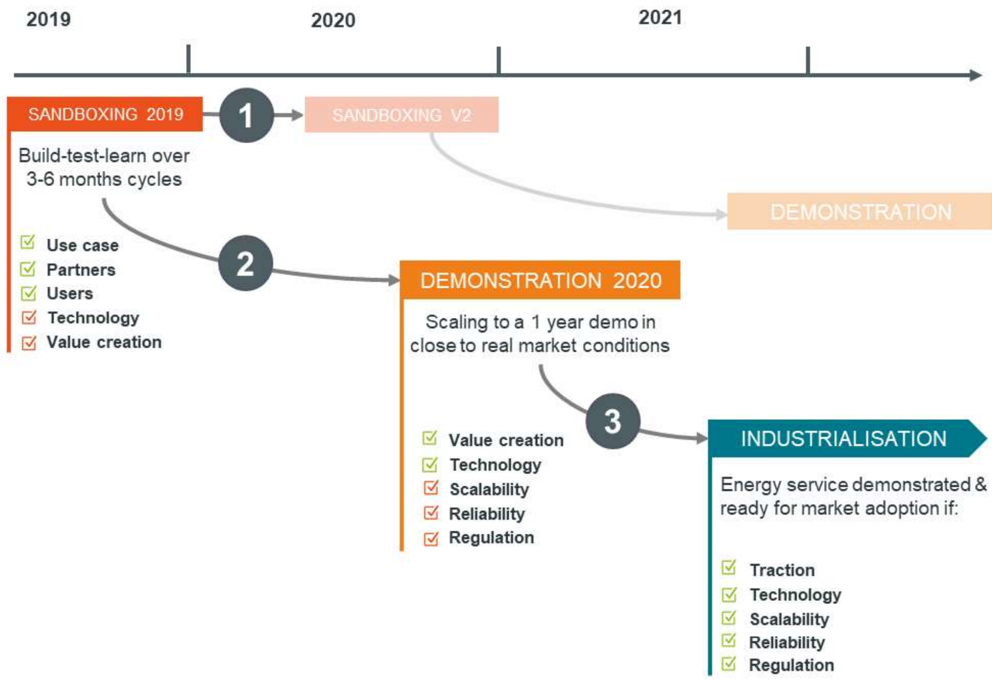


Figure 24 – IO.E planning

- **Sandboxing**: Three to six months of step-based testing involving a small number of consumers to validate the basic idea and verify that the technology can deliver. Several groups, some led by Elia (involving different group of actors) are developing their use cases under the same sandboxing step. It should be noted that the IO.E project will now enter in this phase.

- **Demonstration:** The lessons learned from the sandboxing step and the most promising use cases are merged into a large scale demonstration developed over a period of 1 to 2 years in close to real time conditions. The objective there is to assess how and if the Energy services and the related regulated processes can be scaled and what would be their impact on power system reliability.

- **Industrialisation:** The services have been proven scalable and is put on the market by the market actors at its origin. Necessary regulated processes have been successfully industrialised.

The figure 24 presents a tentative timing for the different steps. Due to the high innovative components of this project (most of the use cases are looking at new business models), the planning might change over the course of the next months based on the results of the sandboxing 2019.

If value is proven at the end of this step for the consumers (access to first version of energy services), market actors (capability to deliver a first version of a new offer for their customers) and for the system operators (learnings regarding possible new requirements in terms of regulated processes) the project will move for this batch to demonstration. Proper KPIs in terms of societal value will be defined only at this stage based on the scope of the large scale demonstration.

C. *Context/stakeholders in the project*

As mentioned the IO.Energy project has been launched jointly by the system operators. Elia, jointly with other regulated entities, is ensuring the operation of the open innovation ecosystem. To ensure full neutrality against ideas brought by market actors, the system operators have contracted an external facilitator “co-station” to support them in the stakeholder management as well as the design of the methodology to be used during the different steps.

To properly support the functioning of the Open Innovation ecosystem, the system operators are also relying on external support for different domains that are necessary for such activity:

- Cresco Law for legal advices on contracts and IP requirements;
- Delta EE for supporting the validation of the different use cases definition;
- Energyville for support regarding market and regulatory questions;
- The Beyonders for facilitating the discussion among parties.

Elia and the other Belgian System Operators system operators have also entered into non-commercial partnerships with Flux50 and tweed, two initiatives looking at the energy transition for cross-fertilisation as well as dedicated support (funding search for use cases) in Flanders and Wallonia.

Furthermore, Elia is mandated by the other system operators to ensure the progressive development of the IO.Energy communication platform under the supervision of a group of DSO and TSO IT expert and the steering of the Synergrid market committee. For the development Elia is using a mix of internal experts and freelancer (for the cloud technologies) developing over components developed by Google and Microsoft.

The operational and development costs of the open innovation ecosystem and the communication platform are shared by the system operators.

The project involves also market parties (including academics) which are also participating on a voluntary basis to the IO.E project as part of the different use case teams. Each use case team is in charge to generate its own budget either through self-financing or by contracting subsidies. Listing them all will go beyond the scope of this document but a list of all the current market parties is available on the IO.E website.

D. *Value development plan*

How the project contributes to the strategic objectives

We believe that a new way of managing the future power system is required in order to maximise the benefits of the energy transition for an empowered consumer. This will be possible thanks to a thorough digitalisation of the power system and an adapted market design. Several but complementary approaches are possible towards this objective.

IO.Energy is one of them and is focusing on facilitating the direct test of new energy services to derive what could be the necessary market design evolution and subordinated regulated processes to allow them emerging.

IO.E represents for Elia and the other system operators a novel way to tackle its innovation requirements by being closer to the markets needs and better understand how the consumer can and will become an active part of the power-system operation.

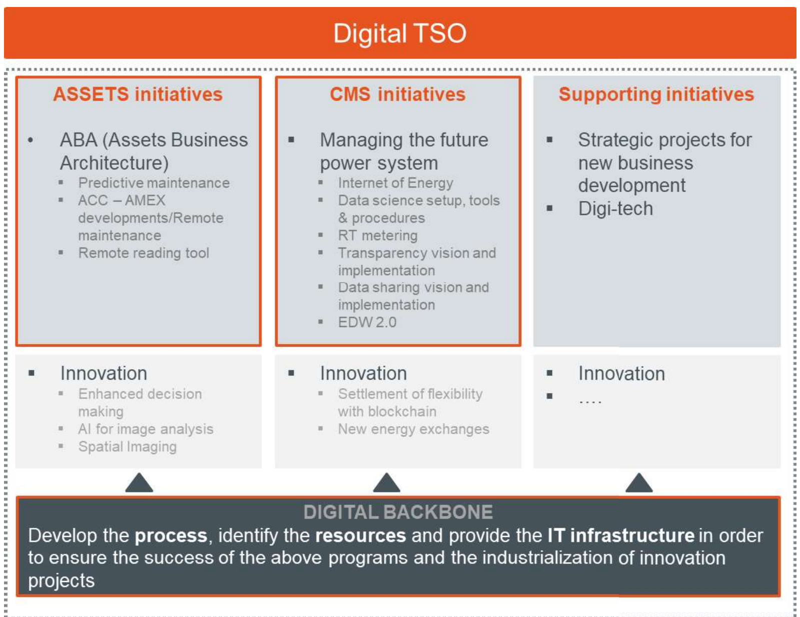


Figure 25 – Digital backbone is a key project of the Digital TSO vision

As mentioned previously, IO.E is already contributing to the evolution of Elia market activities as having contributed already to define tools and business processes for the aFRR available to non-CIPU units.

Furthermore, Elia considers IO.E a key player in the further coordination required between TSOs and DSOs. It allows system operators to reflect on how they could jointly support the emergence of new flexibility means as well as new operational possibilities derived from the availability of end consumers data in real time.

Link with Elia's other innovation objectives

The IO.E project is a "tool" used by other innovation initiatives to directly test their ideas with partners. Among others, it should be mentioned that IO.E is used by the projects:

- Understand the potential of smart pricing;
- Flexity ;

- Integrating decentralised assets in the balancing market.

Implementation plan

The overall planning of the project is presented under the paragraph “Definition of project and planning”.

Potential next steps

The first concrete next step is to support the entry of the current use cases (seven in total) – information about the use cases can be shared on demand – in the sandboxing step and coordinate together with the DSOs the sharing or practices, problems and learnings among all the partners over the next six to nine months.

Following this, we plan a first concrete trial of testing together of energy services for consumers. The discussion will start will all relevant parties to prepare the ground for a possible demonstration towards the end of [redacted].

8. DIGITAL BACKBONE

A. Innovation objective & problem to solve

Problem

Data are often the poor relation in IT systems and usually comes 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 regarding their homogeneity or reliability.

Elia is planning to attempt a paradigm shift where we prioritise 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 further with the introduction of a new ecosystem that complements the existing frameworks, in which data are cleaned up, enriched, connected and tracked.

While the implementation of each of the components of this new ecosystem, whether they are open-source items or subject to a commercial licence, is not an innovation in itself (although some of these will be tested on borderline cases with cutting-edge features), the innovation and the associated challenges lie mainly in their interactions, connectivity and automation. 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): this is the type of features Elia plans to implement and 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.

Finally, there remains the human challenge resulting from this paradigm shift. This involves new ways of working and calls for the acquisition of new knowledge and talents by the users and operators of this innovative ecosystem.

Objective

The Digital Backbone program is a cross-cutting transformation program aimed at introducing a new IT infrastructure based on a modernised organisational 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:

1. 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;
2. implementing the data strategy: a set of company-wide processes and frameworks for managing and integrating data into new technologies and solutions;
3. creating a set of architectural components based on new technological aspects enabling integration and access to cross-cutting data flows;
4. working with human resources and external partners to co-develop the digital skills and data-driven organisation of the future.

Impact for Elia: KPIs and/or hypothesis (qualitative and quantitative)

As a digital facilitator, the KPIs representing the keys to success are not directly measurable in terms of their impact on the company. However, we can define the following qualitative KPIs:

- data maturity at company level;
- the number of integrated applications as a result of the Digital Backbone programme;
- the number of partners interacting with the digital backbone.

Use of the results

Supporting the energy transition						
Improving public acceptance						
Boosting Elia's efficiency levels						
Enhancing market design						

Therefore, the best aspect of the data architecture provided by the Digital Backbone program is easy access to internal and external data, which will mainly improve efficiency and flexibility levels when using data in the company, thereby promoting the integration of renewable energy. The five main anticipated benefits are:

- integrating and passing on to our partners more quickly more accurate, consistent, reliable data;
- sustainably supporting the increase in data volume and agility of processes resulting from the energy transition combined with the digital transformation;
- activating the consumer-centric energy system;
- reducing the digital and technological gap facing our internal resources;

- identification from internal resources in the business of use cases or the better use of the internal resources and the creation of added value via a better internal and external stakeholder engagement.

B. Project definition and planning

Overall type of the project (innovation phase) and program

Validation and pre-exploitation phase

Develop innovative TSO data handling and platform to build digital tools

This transformation program is part of the data strategy the company has set for itself since 2017. In this context, each constituent batch contributes to the company's maturity in the various data disciplines as illustrated in figure 26.

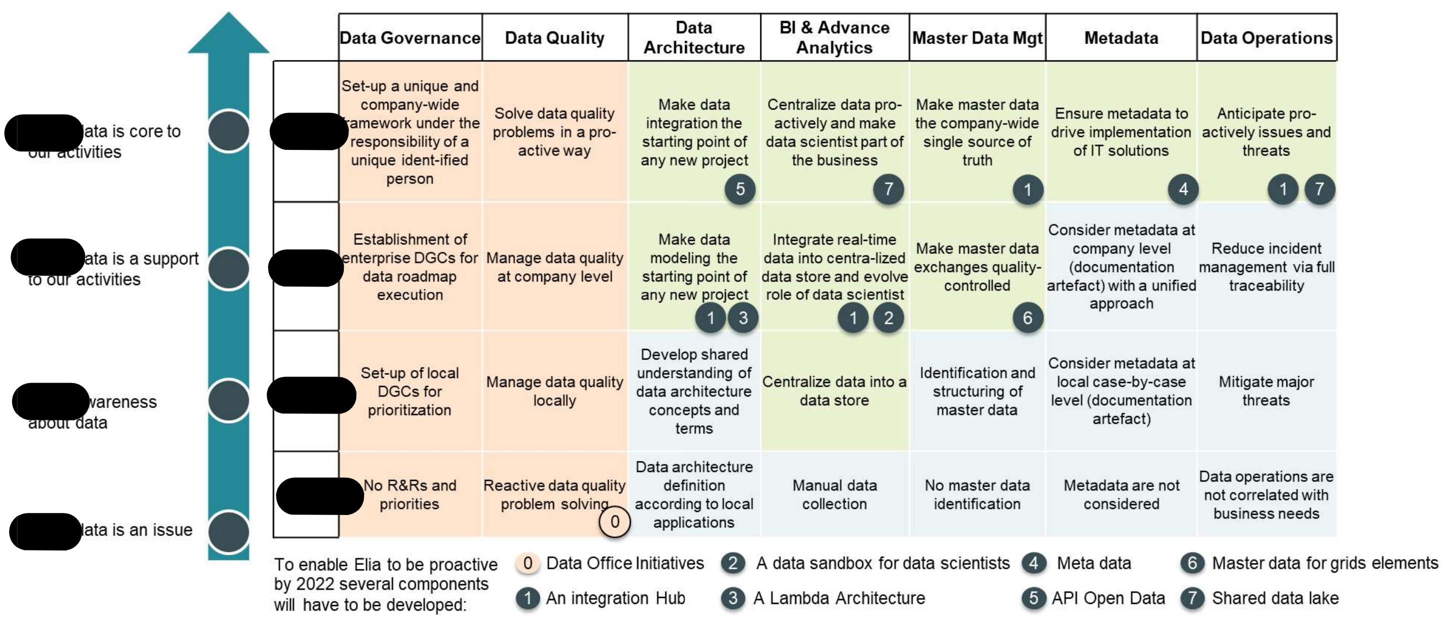


Figure 26 – Digital Backbone timeline and challenges

The various batches of this programme iteratively reflect the following innovation phases in short cycles:

Define

Defining the intrinsic functionalities and scope of each component by referring to representative use cases submitted by the business side of the company and identifying the associated data.

Discover

Discovering the potential solutions and/or technologies to implement, as well as the data sources to consider, that can address the needs expressed in the definition phase.

Develop

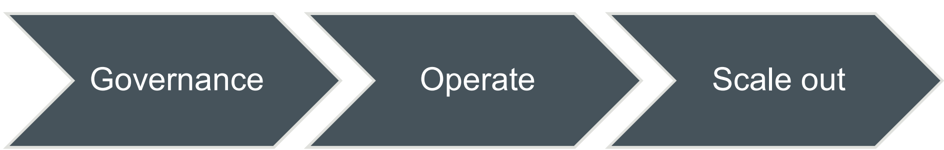
Developing and integrating the various concepts identified during the discovery phase for testing and assessment and checking their impact on the data by adopting a 'learning by doing' approach.

Demonstrate

Demonstrating the added value of each functionality through the use cases submitted by the business side of the company and collecting feedback and experience serving as input for the following iterations and/or the data office.

Note

It should be noted that the following industrialisation phases do not form an integral part of the scope of the Digital Backbone program but are part of the respective transformation programs of the company's operational departments, including the implementation of governance for the operationalisation of the various components with a view to scaling them up.



Separation into work packages

So far, the various identified batches of this program correspond to the various components to implement. They are already charted in the map of the capabilities of the Digital Backbone programme as illustrated below.

Other batches are likely to complement this program, in particular in terms of training and managing the talents of our internal resources and also in terms of testing business cases requiring this Digital Backbone programme.

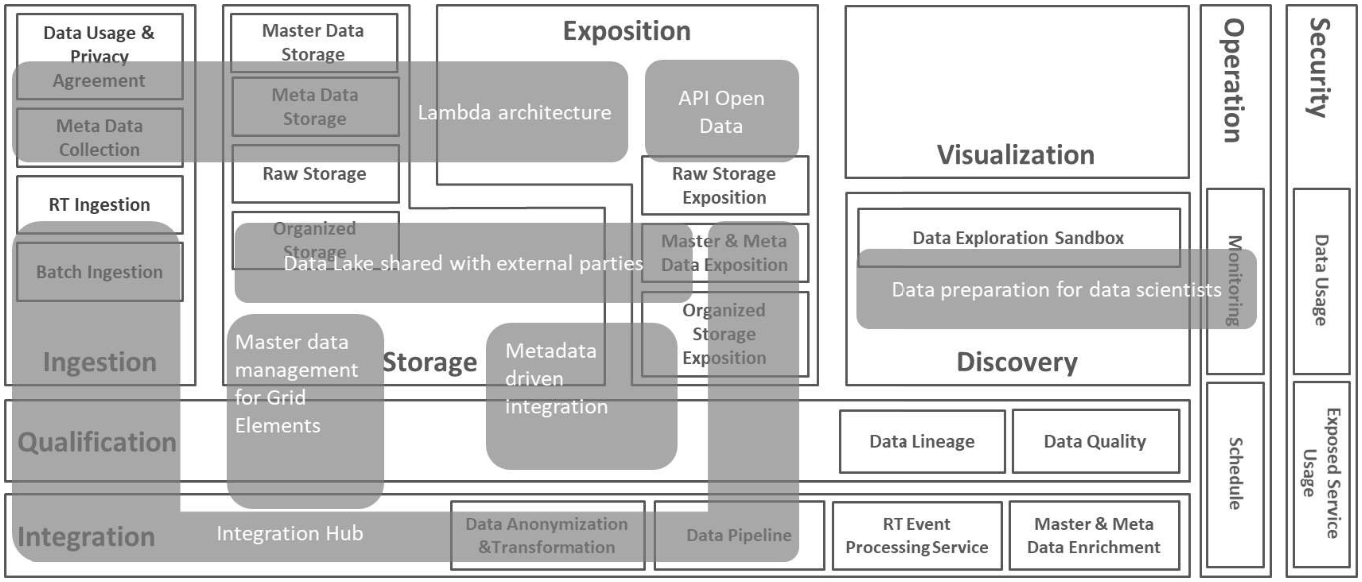


Figure 27 – Digital Backbone work packages

1. Integration Hub

Today gap

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 consumes many hours of development for each release. The reusability of the previously developed integrations is low.

Solution

Create a pilot project to setup the foundations and first iterations of an Integration Hub. Deploying the different technical components needed for an Integration Hub and developing best practices and policies about this Integration Hub.

2. Data preparation for data scientists

Today gap

Each data science project is consuming data. It takes a lot of time to extract these data from the source system. Unavailability of the data is leading to delay in the data sciences projects

Due to large volumes, source systems are definitively deleting data that are never stored anywhere else. We shouldn't consider this as a reasonable approach and we must consider that each data should have an accessible archive at least for data scientist.

Solution

To cover the two goals, we propose to create a pilot project to setup foundations and implement first iterations to provide applied guidance for next iterations on data preparation pipelines and a data lake to store the output of these pipelines. Data sciences projects must source their data from the data lake. Reduce time between the moment the data is required by a data scientist and the data is available for data scientist. Unbind the data science project to the operational source system.

3. Lambda architecture applied to external publications

Today gap

Currently, historical data for publications are sourced by a single source but data for the last few days are not integrated into this data store. When a publication needs both kind of data (recently created and historical data), they are on their own to perform this complex consolidation.

Solution

Lambda architecture integrates different solutions to fill this gap. The first step is to create a hot track (ideally coupled with the setup of the integration hub) and then a service layer consolidating the hot track and a cold track (storing historical data, already existing). Each publication should use this serving layer to consume the merged data.

Constraints

Data Lake and Integration Hub must be available

4. Metadata-driven integration

Today gap

Manually building and maintaining the whole set of artefacts for data integration is a daunting task. At the beginning, it's not necessary a huge issue but the more artefacts you'll have to maintain, less time you'll have to build new artefacts. Soon, the time to maintain existing artefacts is taking so much time that it's impossible to build new artefacts.

Solution

Using metadata (business glossary, technical lineage and data quality artefacts), it's possible to partially automate the development and maintenance of data integration artefacts. Metadata-driven solutions reduce the cost of maintenance and development of new artefacts but also increase quality of the development.

Constraints

Data Lake and Integration Hub must be available

Business glossary, metadata and data quality should be in a much more advanced state that they are nowadays.

5. Open-data APIs

Today gap

Integration of Elia owned real-time data with our external partners and customers is managed on a case-by-case and not on a uniformed way. This creates gaps in our monitoring and testing systems rooting data quality issues. This is also an issue for our data consumers in terms of compatibility. This is also not facilitating the discoverability of the data we're providing to the market. More, the costs for the external partners to develop integration with solution is skyrocketing to integrate with data provided by Elia, giving a poor reputation to Elia.

Solution

Elia must provide a uniformed and modern layer to expose the real-time data to the external providers based on an open-data API.

Constraints

To start this project, the Integration Hub must be available.

To fully finalise this project, the Lambda architecture must be available.

6. Data Lake shared with external parties

Today gap

Nowadays, when two companies want to use each other data (speaking in terms of large historical volumes), they transfer the data to their own environment creating a lot of data movements that consume a lot of resources in terms of man power, money and energy. These movements are also creating many data quality issues and some regulatory questions (GDPR …). More than this, it means that any data analysis is requiring a first step in the hands of data engineers. This first step is creating additional delays in the project's execution. It should not be mandatory to execute the data movements. Private calculations should be executed on the platform sharing the data.

Solution

It will be possible to share data on a data lake (filled by Elia and other parties) and optionally to invoice based on calculation consumptions. This is requiring a lot of governance but this will be a huge added-value.

Constraints

Elia should already have a first set of data available in its data lake.

Underlying technology should be supported by some providers (not the case at this moment but should be the case within two years).

7. Master data management for grid components

Today gap

Many businesses within Elia across CMS, Assets and Infra are relying on a listing of the grid elements (assets or functions) but all of them have valid unique requirements leading to different list of elements.

Solution

We should change the approach and stop to think about a unique repository where one department will fill the database for any business. In place, we must start a real MDM project where we have multiple source systems, each of them is driven by an individual business but must be reconsolidated into a unique point that will expose data to the consuming applications. This unique point must warn the businesses in case of misalignment and each issue must be treated by the different impacted business with a formal process. The more you can automate the process the easier it will be to manage it.

Planning by work package

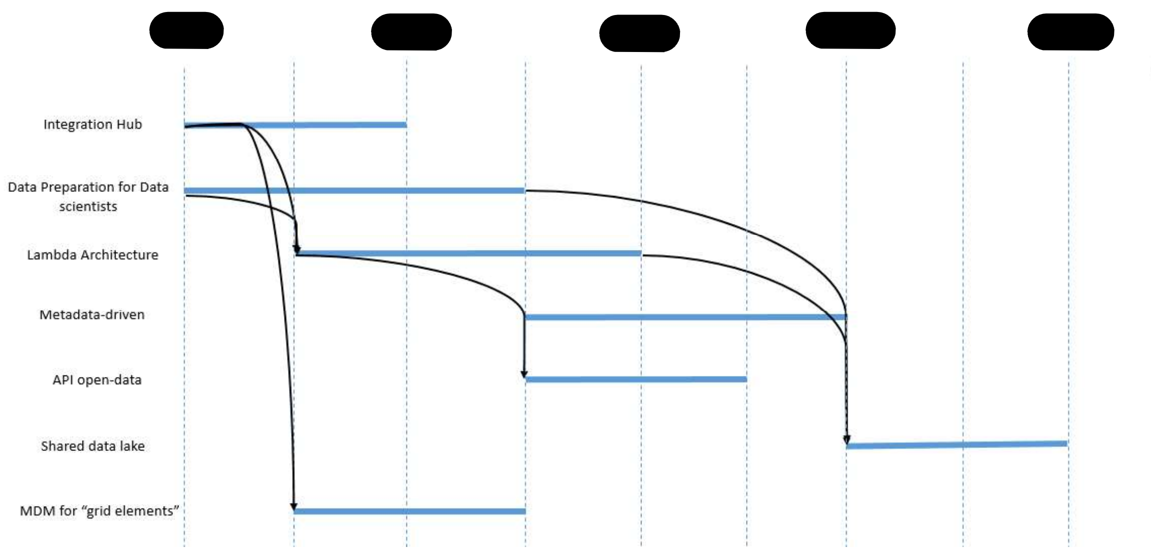


Figure 28 - Digital Backbone work package planning

C. *Context/stakeholders in the project*

Thanks to the open-data APIs and the Shared Data Lake including Data Usage & Privacy Agreement features, the Digital Backbone will be able to support the use of Elia data by any partner such as DSOs, BRPs, BSPs, start-ups and universities and also to collect new types of external data as part of items co-created with these partners.

In addition, certain solution and/or technology providers will be involved in the development of this new infrastructure. Potential candidates that have already been identified include the following:

Provider	Type	Details
[redacted]	Commercial off-the-shelf	▪ .NET technology stack ▪ Application Lifecycle Management ▪ Azure technology stack for core components
[redacted]	Consultancy	for discovery capability of the data

		preparation for data scientists component
[redacted]	Commercial off-the-shelf	[redacted]
[redacted]	Commercial off-the-shelf	for caching capability of different components (integration hub, MDM for grid components, etc.)
[redacted]	Open source	for data exploration sandbox capability
[redacted]	Open source	for containerisation capability of the data preparation for data scientists component
[redacted]	Open source	for programming capability of the data preparation for data scientists component
[redacted]	Open source	for queuing capability of the integration hub component
[redacted]	Commercial off-the-shelf	for communication capability of the integration hub component
[redacted]	Commercial off-the-shelf	for raw storage capability
[redacted]	Commercial off-the-shelf	for storage capability of the MDM for grid components component
[redacted]	Consultancy	for implementation of tailor-made components

D. Value development plan

How the project contributes to the strategic objectives

We believe that a new way of managing the future power system is required in order to maximise the benefits of the energy transition for an empowered consumer. This will be possible thanks to a thorough digitalisation of the power system and an adapted market design. The starting point for all this is “master your data” and common platforms for asset, system operation management and markets that will fulfil current and future needs.
In this context, the TSO of the future will be a fully digital system breaking down boundaries between the different businesses units, hence “Digital TSO”.

The Digital Backbone, forming part of the “Digital TSO” principle, may be understood as a simple upgrade of the current data strategy. However, achieving an ambition is not a result of the design but of resources. The Digital Backbone is all about providing means to our ambition.

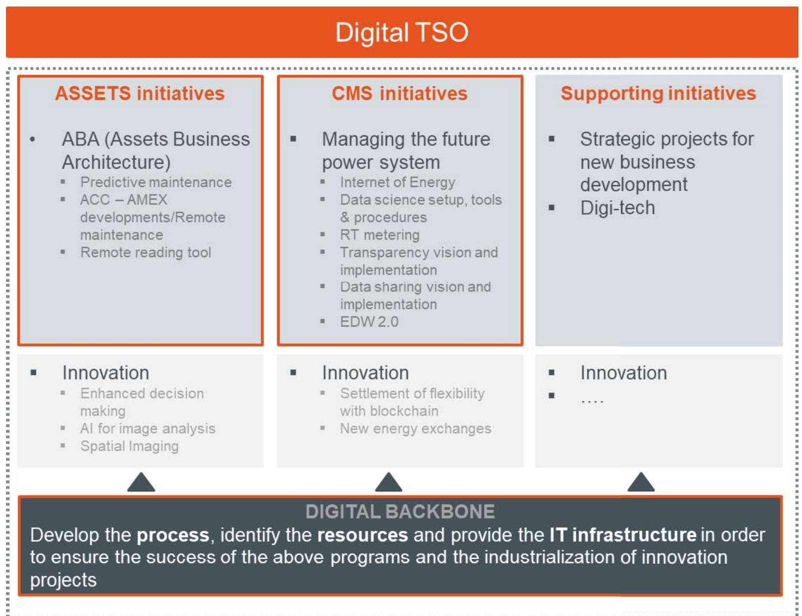


Figure 29 – Digital Backbone – support for the digital TSO vision

As a result the digital backbone will enable many applications that will bring efficiency and flexibility to the daily business of Elia.

Link with Elia's other innovation objectives

The digital backbone and its innovative components are at the heart of the digital innovation of Elia and therefore have a connection with the majority of the project. However, we can particularly note the link with the implementation of digital solution that will benefit from the flexibility of the digital backbone for the project Digital Solution (9).

Implementation plan

The schedule is presented in Figure 28.

Potential next steps

- Operationalisation and industrialisation of the Digital Backbone;
- As a result of the series of integrations, increase in the business cases defined in each division's roadmaps. The innovative business cases will be prepared and presented each year in the report to be submitted before 1 July for the following year. An estimate of the budget for the period 2021 to 2023 has been made and will be refined over time;
- Elia is convinced that the implementation of a digital architecture capable of integrating and managing data between different processes is essential to the creation of new value chains. In order for this digital architecture to meet the

challenges of the energy transition, it will also have to be connected to the IOE (Internet of Energy) platform, thus allowing the development of new services and/or applications more widely integrated into an energy context incorporating all network operators, including new players, from the energy world or not, in the interest of the consumer. Introduction of blockchain technology into the Digital Backbone.

9. DIGITAL SOLUTION

A. Innovation objective & problem to solve

Problem

Elia Assets wants to create **one solution** that will be used a **source for all the Assets maintenance information** giving a view of the assets' health, work items to be performed, malfunctions created on the asset, checks to be performed, links to general information, and so on. This **single point of truth** will be used to:

- make it possible to have a **quick and full feedback loop** from the field operators to the asset managers and the other way around by implementing one end-to-end solution that allows all teams to work in the same tool minimising the feedback time and maximising the responsiveness; in the end the **field staff truly become the eyes of the asset manager**, making it possible for the asset manager to adapt policies quickly with an immediate impact on the ground;
- **adapt the assets maintenance** approach, support the move from time-based maintenance **to condition-based** maintenance via digitalisation;
- have a **digital platform** that allows easy and quick adjustments **to adapt to the evolutions of the energy landscape**; this platform will be maintained and configured by business (and not IT);
- **increase the efficiency** of the internal workforce by simplifying the administration and by giving access to all necessary documents from **one single starting point** for the asset maintenance;
- support more flexible work by giving an overview of the work which has to be done and by giving access to the reported malfunctions on the assets, **empowering the field staff** to determine which tasks must be performed;
- implement an agile way of working within Assets to quickly implement new business needs within the platform;
- **standardise processes** between the Assets Departments to simplify the business, remove historian needs, ease the integration, and so on;
- **support system view-based asset management** via a connector with a **CIM-**compliant integration hub (eliminate point-to-point connections);
- **motivate and support co-creation** by changing rapidly adapting processes based on the feedback of the users;
- use new tools (smart phone, tablets, etc.) and geo-location to quickly give an overview on the nearby assets and the open work items;
- grant access to external workforce and give limited rights to update the status of the work to facilitate the follow up by the Elia staff; gradually the external staff will gain more access to the data allowing them to better support the Elia agents.

This platform will support Elia to adjust quicker and better to evolving energy landscape and be ready for the future. Having an **end-to-end solution for as well field operations as assets performance management** will put Elia in the **front seat of the digital pioneers** for TSOs.

Objective

The current energy landscape will change substantially over the next few years, in particular due to new technologies and the decommissioning of nuclear power plants. This will result in many new IT developments being launched. Elia's current IT landscape has a 'spaghetti structure', i.e. a structure where many independent IT applications are connected through various interfaces. These create a very complex structure that requires a lot of maintenance needs and is not ideal in terms of the reliability of the data set, making decision-making more complex.

As a first step, an industrial survey about the Assets Business Architecture was conducted. This has led to the creation of a new programme, which can be considered an experimental development supported by various software developments, namely digital solutions whose main aim is to simplify the IT architecture and prepare the Assets Division for the changes in the energy landscape.

An example of the application of digital solution is the development of application for the mobile worker using geolocation to provide relevant info to the maintenance worker to improve efficiency and security (e.g. information about the assets, info about the status of the asset in real-time). Figure 30 present a screenshot of currently developed application like the eTripLog the first app using the geolocation to check the entrance and exit from substation for example.

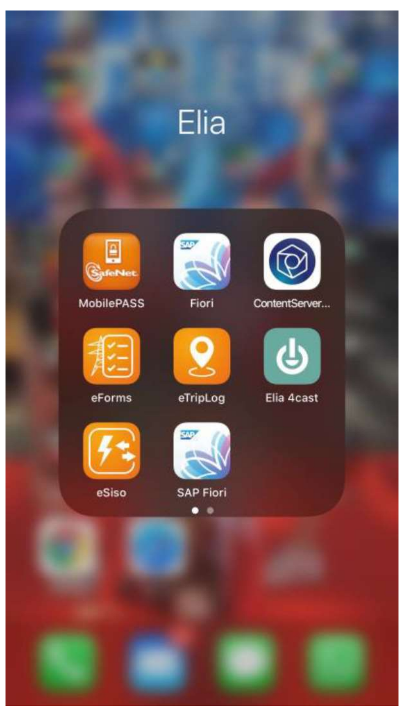


Figure 30 – Screenshot of application that are developed to enable the digital worker and that are based on the digital solution

Impact for Elia: KPIs and/or hypothesis (qualitative and quantitative)

The program's main aim is to offer a new platform providing support for other programs. Therefore, the impact is not direct, but it is clearly a key factor in the other projects' success or otherwise.
Key to success: The project will be successful if the number of applications in Elia's landscape can be reduced. This is essential if we want to improve usability for users, but more importantly if we want to give a better overview of the data. This will ensure that the data will be of a higher quality and will be available more quickly, enabling users to make efficient and fast decisions based on the information in the system.

Use of the results

Supporting the energy transition						
Improving public acceptance						
Boosting Elia's efficiency levels						
Enhancing market design						

Elia must ensure the safety, reliability and efficiency of the electricity network. By developing a new IT architecture, Elia will have access to more and better data. In addition, the data structure will also allow decisions to be made more quickly and to shift from a reactive working method to a predictive one, which will enhance the safety, reliability and efficiency of the electricity grid.

B. Project definition and planning

Overall type of the project (innovation phase) and program

Pre-exploitation phase

Develop the digital worker tools and capabilities

Separation into work packages

1. European Tender: to select the best package for Elia needs at a sharp price.
2. Integration and Baseline: Integrate the new platform into the Assets IT landscape and create a baseline for the field agents and asset managers to start working with the tool.
3. Activate activities: Increase the use of the tool by migrating assets 'activities' into the tool.
4. Maximise platform potential

Planning by work package

1. [redacted]- European call for tenders
2. [redacted]- Step-by-step implementation starting with a baseline. Integration with Elia applications (see Figure 30)

3. [redacted]- Continued implementation by activity and training of key internal users. If possible, start replacing the existing Elia applications.
4. [redacted]- Take control of the platform and adopt it (configure it) based on Elia's needs.

C. Context/stakeholders in the project

The new provider of this platform (call for tenders in progress) will be a very important partner. We are expecting this partner to provide advice not only on how the platform works but also on how certain processes can be managed based on their experience acquired in other companies. In addition, the partner must have a community of users which Elia can be invited into. In this community of users, we plan to learn from other companies, see what new technologies will be developed and express our needs for the future.

D. Value development plan

How the project contributes to the strategic objectives

1. Digital Innovation
- Increase availability of data and information for all the staff of asset management department to improve and speed up decision-making.
- Enable view of assets status aggregated for different levels and make it clearer when action is needed (e.g. replacements).
- Improve performance by minimising administrative overheads.

2. Prepare for electrical transition
- Change internal way of handling new challenges by no longer starting smaller projects in a classical way but allowing business (with the necessary support) to adopt their processes within a digital platform.
- Use the Agile methodology to adapt incrementally to the changing environment and improving and adjusting the solution with every step according to new insights/needs.
- Prepare field agents to work more flexible and be able to make choices by given all necessary information and a clear overview the status of the assets, the work necessary, the open issues… via a personalised dashboard.
- Give access to external users to support Elia when needed.

3. Increase efficiency
- Support the switch of time based maintenance to conditional based maintenance and so only perform work when it is needed.
- Cut down the administration, the search for information and the use of multiple applications by creating one single point of truth.
- Have immediate access to information via the feedback loop making it possible to adopt policies as quick as possible.

- Via the introduction of new standard processes the 'extra' actions will be removed from the processes. Next to this the learning and adaption time for the users will be decreased.
- Allow specific activities to external parties to ease the follow up and decrease the administration for the Elia agents.
- Cut down on paper by creating more digitalised forms that are available to internal and external personnel, thereby also reducing the time needed for e.g. printing, copying, scanning and sharing hard copies.

Link with Elia's other innovation objectives

- AMEX: Give the Asset Managers a full view of the status of their assets and aggregate this view on different levels. Help the asset managers modify the maintenance policy from time-based to condition-based maintenance.

- ACC:
  Integrate with the ACC solution to give a full view of the assets' health index by using information gathered by both solutions.

- OPTIFLEX:
  Prepare the field staff to work more flexibly and make it possible for them to make their own decisions with regard to carrying out maintenance works. Ensure that the planning can be done quicker and further in advance.

- DIGITAL BACKBONE
  The new platform will be using the technology provided by the Digital Backbone. Alongside this it will be a provider of data for various purposes.

Implementation plan

1. [redacted]- European call for tenders
2. [redacted]- Step-by-step implementation starting with a baseline. Integration with Elia applications.
3. [redacted]- Continued implementation by activity and training of key internal users. If possible, start replacing the existing Elia applications.
4. [redacted]- Take control of the platform and adopt it (configure it) based on Elia's needs.

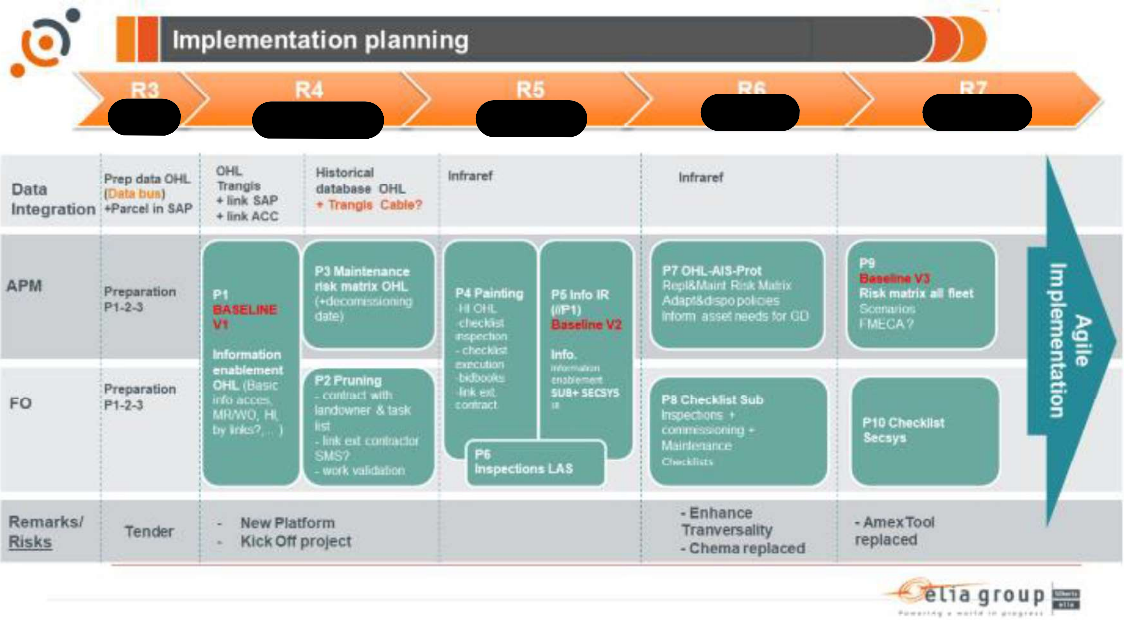


Figure 31 - Planned timetable for implementing digital solutions

Potential next steps

In a first step the platform will be used for Asset Performance Management and Field Operations. After this implementation a potential next step is to introduce outage management to the platform. This will give a very important information advantage to request, plan, prepare and view the outages. But is will also help to a have a better view on the impact of the outage, of which work can be performed during an outage, to follow up on this. All of this will improve the efficiency greatly.

10. AUTOMATION OF VOLTAGE CONTROL

A. Innovation objective & problem to solve

Problem

Voltage control in the high voltage network is becoming more and more complex, driven by multiple factors. Firstly, small and intermittent distributed energy sources are emerging, which means that conventional power plants are decommissioning. These conventional units are until today the most important means to manage voltage control. Next to this, more and more overhead lines are being replaced by underground cables that generate much more reactive power. These cables are then compensated by switchable and variable shunts distributed in the network. A third evolution is the increase of active power exchange capacities, by upgrading interconnections, which implies that the Belgian power system, driven by the European market, is becoming highly flexible.

A general approach of TSOs to solve voltage problems is to revert to the installation of power electronic assets such as STATCOMs, which are devices that are quoted with prices ranging well above several millions of euros. At Elia, we want to assess the possibility to avoid such investments, by optimising the usage of voltage regulating assets we have today (e.g. shunt or capacitor bank).

Objective

The goal of the project is to support the dispatcher in managing the voltage plan and Mvar distribution on the grid. The project is currently divided into two independent parts. The first part aims at the development of a decentralised control mechanism or algorithm, which will autonomously take decisions of connecting or disconnecting a voltage-regulating asset (shunt or capacitor bank) following an incident. The second part consists of introducing an optimisation controller in the dispatching, that will help the dispatcher in always reaching the optimal voltage spread over the grid and minimise the costs. Eventually, the experience gathered in those projects shall be used to pave the way for automated voltage regulation.

a. Automatic local voltage regulation

Following the trends as described earlier in this report, the grid is operated closer to its limits than ever before. This makes that in certain cases it is crucial to react quickly in case of contingencies. The goal of the first part of the described project is to automatically control shunts or condenser banks in critical areas in case of contingency or extreme situations (e.g. load, RE production). In that way the dispatcher will be supported when the voltage rises too high or too low, because at a certain threshold level the compensation element will automatically aim to stabilise the voltage, thereby acting as corrective and curative compensation. The elements will react within very short time frames; this means that the system will be more responsive than depending on humans alone. One of the key considerations of the project is to make sure that no harmful interactions can take place, i.e. two decentralised controllers cannot take conflicting decisions at the same time.

b. Tertiary voltage control

With an increasing volatility on the high voltage grid, and more reactive power supplying units that will arrive with the new Mvar design, it will become impossible for the human brain to arrive at an optimal voltage plan, taking into account costly and (preferably) non-costly measures, energy production predictions, local consumption patterns etc. Therefore, the goal of the second process is to assess the creation and implementation of a tool that will support the dispatcher in taking decisions related to the voltage plan. Practically, for instance once every 15 minutes, the tool will propose the actions to take to the dispatcher in order to reach an optimal voltage plan. This tool will need to take into account existing predictions for load and production and consequences in terms of N-1 security of its decisions. On top of this, the tool will need to be able to cope with the complex world of voltage regulations, in which many actors and influencing factors play a role, such as local load fluctuations, voltage management of neighbouring TSOs, voltage-regulating assets and transformer tap changers.

Impact for Elia: KPIs and/or hypotheses (qualitative and quantitative)

For the first part of the project, we want to assess whether automatically switched assets can support the dispatcher in avoiding under or over voltage situations. If a contingency occurs, followed by a significant deviation from nominal voltage, this might lead to potential unsafe situations or violation of the operation criteria. Therefore, the main hypothesis to be tested is whether a decentralised, automatic system is capable of keeping the grid voltage within accepted boundaries without any unwanted side effects. Furthermore, we need to be sure that our assets and way of working on the field can withstand this type of automatic switching.

In the second part of the project, the goal is to assess whether an automated tool is able to optimise voltage management in real time. The goal is to arrive at a tool, based on an algorithm (business needs) or AI-based, which will help dispatchers from both national and regional control centres to keep the voltage plan of the grid at optimal level. We want to assess whether such tool is able to optimise the voltage plan in a sense that takes into account N-1 after the proposed actions, and anticipate the forecasts for load and (renewable) generation. The tool shall propose actions to the dispatcher in a way that it is possible for the latter to follow them in real time, and reflection is to be made on the future question of whether such tool can eventually manage the voltage automatically, without human interaction.

Use of the results

Supporting the energy transition						
Improve public acceptance						
Improve Elia's efficiency						
Improve market design						

The Mvar projects are expected to have various benefits.

Firstly, the reactivity in case of contingency will increase. This means that in situations where speed of reaction is crucial, the dispatcher will be put under less pressure, since the automated mechanism can take decisions for him and turn away e.g. a voltage collapse, thus result in a better network stability.

In addition, in view of the increasing complexity of voltage regulation, the dispatcher will receive assistance to keep his network under control. This also means that, if trust is gained, the network can be exploited closer to its limits and then we can avoid unnecessary investment in voltage regulation assets or upgrade of the substation. Voltage coordination will be better performed, thus Mvar exchanges between different zones and voltage levels will be avoided, and the overall Mvar balance of the grid will be improved. Another assessment to be made is whether this improved voltage regulation can result in lower costs for Mvar absorption and production.

B. Project definition and planning

Overall type of the project (innovation phase) and program

Exploration phase

Prepare for the system operations in the new context (HVDC High RES penetration…)

The first part of the project is considered to be incremental/breakthrough innovation, in the validation stage, and is therefore led by the business (national control centre project lead, support by innovation department).

The second part is considered to be breakthrough innovation in a testing phase, which means that it will be led by the innovation department in close collaboration with the national and regional control centres.

Separation into work packages

In general, the Mvar project acts as an umbrella for two separate projects, these being (i) automatic local voltage control and (ii) global voltage plan optimisation.

The first project has been split into four work packages:

1. Areal localisation: definition of a substation where there are voltage issues and the needed assets are already available
2. Design criteria: definition of response time, dead band, algorithm functioning, etc.
3. Field implementation: implementation of the defined solution in a substation
4. Analysis: validation of KPIs and analysis of POC results

Most focus will need to be put at WP 2, the development of the design criteria, since here the critical aspect of unwanted interactions between closely located assets is to be assessed.

The second part of the project is currently in a phase in which existing solutions and external experience needs to be benchmarked. Following the outcome of this exercise, a clear view on needs and planning will be available.

Planning by work package

No planning ready at the moment and will need to be defined in the months to come.

C. Context/stakeholders in the project

The project is performed in the context of the increasing complexity of managing the voltage of the high voltage grid.

The main stakeholders are the national and regional control centres, since they will be ultimately responsible for voltage management. Furthermore, close relations will be maintained with Elia's Artificial Intelligence laboratory (from innovation), in order to understand how machine learning could support this project.

[redacted]

D. Value development plan

How the project contributes to the strategic objectives

The project is preparing the grid for the future. If the automatic voltage control implementation is successful, we will arrive at a secure, reliable and efficient grid control. These aspects will be reached because human error can be minimised, and speed of reaction will be increased.

Of course, the project dovetails perfectly with the 'Eyes wide open on innovation and growth opportunities' strategic objective, since we will leverage the current status of data science and technology to facilitate the dispatcher with voltage control.

Implementation plan

The implementation of the projects depends on the outcome. For the first part, if we see an added value of the algorithm, and no potential situations in which it could negatively impact the system exploitation, the project will be transferred to the department of secondary systems within asset management for implementation.

The second project is in an earlier innovation phase. The experience that is gained with the project will lead to follow-up projects, which will assess the potential of an automated voltage optimiser and eventually lead to the implementation of such a tool as part of dispatching.

Potential next steps

The ultimate vision of Elia's Innovation Department is to achieve an auto-pilot for dispatching. This means that all steps, including voltage control, in normal situations should be handled by digitalised systems. Therefore, this project acts as a first way of sensing

11. DEVELOPPING AN UNDERSTANDING OF FUTURE GRID DYNAMICS

A. Innovation objective & problem to solve

Problem

Since electricity grids are subject to both injections and offtakes of energy, it is only natural that there will be imbalances between generation and consumption. Such imbalances have an impact on the frequency level. In parallel, 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 of the load. This inertia is necessary to ensure that the network can overcome an imbalance between generation and consumption and become stable again. A grid's inertia level affects the rate at which the frequency changes. The lower the inertia level, the faster the frequency changes when there is an imbalance between generation and consumption. The frequency of the electricity grid must be stable because any major fluctuation in the frequency level can very quickly spiral out of control, as the size of the fluctuation has a direct effect on how fast the grid becomes unstable. Indeed, if the frequency deviates from its stability range (from 48.5 to 51.5 Hz), there is a significant risk of a grid blackout.

We should distinguish between the problems of <u>overall inertia</u> in a synchronous area and of <u>local inertia distribution</u>. The first issue is studied by ENTSO-E as well as in the WP2 of this project, while the second is examined by the WP1 pf this project. 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". This refers to the unscheduled power cut in Germany on 4 November 2006 that split the European system into three areas and caused a blackout meaning that some 15 million people were without power for two hours. The report continues: "As long as the system remains interconnected lower system inertia [than the grid's current value] is not considered to be critical for the normative 3000 MW incident." In other words, the instantaneous loss of capacity equivalent to about two nuclear power plants in Continental Europe will not, under normal circumstances, lead to a drop in frequency that could lead to a blackout. With the advent of renewable energy and the exit from nuclear power (and therefore the withdrawal of large generation units), we need to ask ourselves whether we are not perhaps moving towards an overall inertia problem and whether there is a way of power electronics providing inertia to the system virtually. This is the purpose of our WP 2 of this project.

During discussions between Elia, National Grid and various universities it became clear that inertia distribution can also have an impact at local level, especially in a smaller synchronous system, as in the UK. National Grid is currently reviewing the results of a series of nationally funded research projects in this area to understand the implications. Due to the geographic redistribution of generation units and the shift in these towards technologies that provide no or little inertia, Elia is also interested in the problem of the local distribution of inertia (WP 1) which complements WP 2.

Finally, Elia is also curious about the integration aspects of these new technologies in the existing system from a simulation perspective with a view to ensuring that we can simulate the new dynamics of the system by integrating all the new parameters brought into play by power electronics. This is covered by WP 3.

Through these various work packages, we are trying to understand the change in the dynamics of the grid by supporting PhD and other research projects dealing with this subject. The penetration of power-electronics technologies is affecting grid dynamics. This means we have a duty to understand these new dynamics and ensure we can continue to operate our grid reliably and without an impact for our users.

Future power systems are facing new challenges when traditional thermal generation units are replaced by renewable energy sources with power electronic grid interfaces. In central Europe, an increasing share of wind and PV generation in the energy mix is leading to periods with few synchronous generators in operation, and the resulting low equivalent rotating inertia in the grid can introduce stability problems. Scenarios with low inertia, leading to challenges with frequency control and grid stability, are already requiring attention in the transmission networks in UK and Ireland. In the Nordic countries of Europe, low equivalent inertia is expected to produce potential issues within 2025. Different control schemes have been proposed for providing virtual inertia from power electronic converters distributed generation and other low voltage applications. Especially HVDC converters may represent an effective solution for alleviating issues caused by decreasing rotating inertia due to the significant installed power rating. However, identification of the most suitable implementation methods for HVDC converters with different topologies is still an open issue. This project will develop methods for assessing the value of and the requirements for inertia emulation from HVDC transmission schemes. Furthermore, control strategies suitable for inertia emulation by HVDC converter stations with different power converter topologies will be developed, and their performance and stability characteristics will be analysed. Detailed models of HVDC transmission schemes with inertia emulation capability will also be developed for analysing the influence on the stability of large-scale power systems. The methods and techniques resulting from the research activities within the project will support the development of "smarter transmission systems" in a future context with limited physical inertia from traditional generation plants.

Objective

Elia has a strong objective: make the energy transition to fulfil society's ambition. In order to achieve a carbon free power production park, RES and decentralised production will have to be massively integrated in the system, bringing their complexity to manage the grid with high efficiency and reliability. To achieve this goal, our experts must understand the new dynamic the grid will be exposed to. A project composed of 3 work packages is running in the next years:

- **WP 1: Study on local Inertia status (local inertia)**: This project studies phenomena related to inertia distribution that can have a significant impact on the operation of the electricity grid. The mass influx of renewable energy is reducing inertia and therefore the grid's ability to withstand major incidents such as the shutdown of a nuclear unit. The project, led by Elia, is aiming at developing modelling tools and expertise by bringing to light the effect of inertia distribution on electricity grids.

- **WP2: Study on the provision of virtual Inertia (virtual inertia):** This work package focuses on improving the understanding of inertia problem, the economic and technical feasibility of inertia support with HVDC.
  - Primary objective: Develop new methods and tools for enabling HVDC interconnectors to improve system stability by delivering inertia support, and by this contributing to future stable and secure operation of the European power systems with an increased share of renewables.
  - Secondary objectives:
    - Quantify the potential technical and economic benefits and implications of operating HVDC interconnectors for inertia support from a transmission system perspective;
    - Define and analyse suitable strategies for providing virtual inertia from HVDC terminals by acting on external reference signals or by dedicated internal control strategies;
    - Develop new techniques and tools for accurately assessing small- and large- signal stability in large scale power systems with inertia support from HVDC transmission schemes;
    - Demonstrate virtual inertia control in a laboratory environment, targeting a TRL of 4/5.

- **WP3: Study on impact and opportunity of power electronics for the network (InnoDC):** For this work package, a PhD student is studying the *Dynamic stability of power systems with high penetration of power electronic-based interfaces*. This research is conducted in the scope of InnoDC consortium under the direction of the European Commission. In total, 15 research studies are taking part to this analysis called InnoDC. The main focus of the project is to analyse the dynamic stability of power converters, starting from a detailed evaluation of how to represent converters and their surrounding AC power systems for system-wide dynamic stability analysis. Due to the large bandwidth of the converters and their controllers, dynamic interactions with the surrounding AC systems are no longer necessarily limited to low-frequency interactions, but can also include higher frequency resonances between the AC systems and different converters, amplified through the converter controls. These relatively new types of interactions are challenging the use of traditional phasor-based analysis tools for studying the system dynamics. The project aims at understanding and defining the limits of phasor-based models for local and system-wide control studies involving high amount of power electronics and propose solutions for the modelling and simulation of such issues. The results will provide guidelines on the level of details needed to analyse various dynamic phenomena in the AC system. The findings of the dynamic stability study will be benchmarked against an EMT implementation.

Impact for Elia: KPIs and/or hypothesis (qualitative and quantitative)

As this initiative is related to mainly R&D studies the next step is not for implementation but fore validation. Therefore, there is no quantitative business case but hypothesis that we would like to validate or not in order to shape further validation of concept and ultimately a potential implementation.

During WP 1, Elia wants to investigate the following points:

- understand the nature of the possible effects of inertia distribution;
- conduct a more detailed study into the impact of poor inertia distribution on Belgium and continental Europe;
- identify mitigation measures.

During WP 2, Elia wants to verify the following hypothesis:

- Is HVDC a cost-effective way to supply inertia?
- Can we export inertia to neighbouring markets (UK)? Can we move inertia in the continental system? (ALEGrO)
- What are the technical requirements to supply inertia?
- What should be included in the grid code for HVDC?
- How much inertia can a connector supply?
- What are the different positive and negative impacts on the system?

During WP 3, Elia wants to verify the following hypothesis:

- What are the theoretical limitations in the accuracy of phasor-based representations?
- What is the accuracy of various RMS models of power system components and what stability issues are these models able to represent?
- What are the main stability issues in a power system with several converters embedded into the system?
- How is the accuracy of the phasor-based models affected by different system parameters? (short-circuit ratio, local inertia)
- What component details are necessary in order to ensure an accurate

representation of these stability issues?
- What indicators (KPIs) can be used to analyse the validity of a model for a certain stability study?

Use of the results

Supporting the energy transition						
Improving public acceptance						
Boosting Elia's efficiency levels						
Enhancing market design						

B. Project definition and planning

Overall type of the project (innovation phase) and program

Exploration innovation

Prepare for the system operations in the new context (HVDC High RES penetration…)

Separation into work packages

As explained in the previous section, this subject is split into three work packages. Each one of them is split into sub-tasks.

WP 1. Local inertia

Specific events in the United Kingdom have identified several possible effects resulting from unequal inertia distribution. Several examples of these effects are presented below:

- activation of RoCoF (Rate of Change of Frequency) protection in some places: a RoCoF protection is, roughly speaking, protection that is triggered as soon as a given Hz/s threshold is reached, thereby protecting the grid from abnormal situations. National Grid has already witnessed RoCoF-protection activations due to a high RoCoF measurement. A potential solution (which indeed has already been applied) is to release the RoCoF set points for protection systems with a view to delaying the decoupling of operating units from the grid in case of frequency deviation problems. However, this is an expensive solution, and there is no obvious alternative to activating the protection system;
- inter-area oscillations: National Grid monitors the oscillations between the north and the south of the UK and intervenes to maintain frequency damping. This may can lead to stability problems at the generators involved in the oscillations. These may also occur in transit areas when the energy flow increases.

Elia intends to further investigate the potential transposition/extrapolation of these effects to a wider synchronous area, with a focus on possible 'local' repercussions in Belgium due to unequal inertia distribution in Continental Europe.

Before analysing the phenomena and potential mitigation measures in detail, Elia conducted an analysis with Brunel University London to gain an understanding of the nature of the possible effects of inertia distribution. The aim of this first phase was to understand if a local (i.e. Belgian) phenomenon or the behaviour of neighbouring grids could have an impact on the stability of the Elia grid requiring an intervention involving local inertia.

The results showed a need to investigate this subject further. As a result, a new phase of the project will be launched. This second phase will feature the following steps:

Part 1: Examining the RoCoF algorithm on Elia grid

The theory of this step is already developed in Phase 1 and it was tested on a reduced UK model. In this phase, Phase 2, the proposed algorithm should be examined on Elia grid to assess its performance practically on a real power system. For this, the researcher should apply the algorithm on Elia's grid, obtain the results and discuss them with Elia and the supervising university. Please refer to the timing in the relevant section for the timing of this part.

Part 2: Transient stability

The basic mathematical approach for analysing the effect of inertia distribution on transient stability was introduced in Phase 1. In Phase 2, a criteria should be developed to quantify and measure the risk of such issue as one already done for local RoCoF. The performance of such algorithm should firstly studied on standard models and then should be examined on Elia's grid.

Part 3: Small signal stability

This step is very similar to Part 2 but the small signal stability and power oscillations of tie-lines will define the quantifier.

WP 2. HVDC inertia provision

The main research question behind all tasks within the project will be how to address theoretical and practical issues that must be solved to ensure technically and economically effective utilisation of HVDC connections for supporting the stable operation of future power system scenarios. The experience and knowledge of all involved partners will be utilised to prioritise the most relevant cases and examples that will be studied.

Part 1. Feasibility and benefits for the power system of HVDC inertia support

<u>Objective:</u> *Quantify the potential technical and economic benefits and implications of operating HVDC interconnectors for inertia support from a transmission system perspective*

- Task 1.1: Data collection and literature study on the quantified needs for inertial response support and the possible implementations
- Task 1.2: Preparation of user-defined case studies
- Task 1.3: Analysis of the potential benefits and implications of operating HVDC

interconnectors for inertia support from a transmission system perspective
- Task 1.4: PhD study at KU Leuven (Prof. Van Hertem).

This part of the work package will analyse current literature related to inertia support as an ancillary service, and on the operation and control of modern HVDC transmission systems, including potential future multi-terminal configurations with connections offshore wind farms. Input is expected from the project partners, both for identifying critical cases where inertia support will be required in the future and regarding operational experience of HVDC transmission links. From the collected information, reference scenarios and cases for further analysis will be defined in agreement with the project partners.

Equivalent models of inertia provision from HVDC will be developed, based on models already available from industry and research partners. The models will be implemented in a commercial software for power system stability analysis (e.g. PSS/E, DiGSILENT or similar) to be agreed with the partners. The simulation models will be adapted by adding functions to the HVDC converter models for representing the inertia support strategies, but maintaining a relatively low detailing level. For example, the steady state and dynamic regulation characteristic can be represented by simple mathematical expressions while limitation factors in the converter could be represented by adding delays, saturations or slew rate limiters. A large number of simulations, for example based on a Monte Carlo sampling, will be conducted for each control configuration, with different generation profiles, loadings, network configuration and perturbations, to identify the required dynamic performance of the inertia support. Moreover, the technical limitations and potential economic benefits of inertia exchange via HVDC interconnectors will be quantified. This will be the focus for the PhD study at KU Leuven, which will be supported also by activities at SINTEF (Scandinavia's largest independent scientific research organisation) and NTNU (Norges Teknisk Naturvitenskapelige Università).

The results of the simulation studies within the Work package part will be used to identify the most adequate requirements for inertia implementations to provide recommendations for the TSOs. This will also include assessment of how much inertia provided at one side of an HVDC interconnection can be allowed to influence the power system on the other side of the interconnection. The results will also be analysed to identify trends or patterns depending on the network configurations, which will be used to specify cases of particular interest to the partners for further investigation in part 3.

Part 2. Control design and interface to HVDC controllers

<u>Objective</u>: Define and analyse suitable strategies for providing virtual inertia from HVDC terminals by acting on external reference signals or by dedicated internal control strategies.

- Task 2.1: Assess level of access for control of different HVDC converters;
- Task 2.2: Depict possible implementations depending on level of access to the HVDC converter control system;
- Task 2.3: PhD study on implementation and control system integration of inertia

support schemes at Ecole Centrale de Lille (L2EP), (Professor Guillaud).

For development of new HVDC connections, it can be possible to introduce implementations of inertia support schemes that are not compatible with conventional PLL-based control strategies. However, retro-fit of inertia support capability into existing interconnection will be constrained by the allowable interface to existing installation. Thus, it is relevant to provide multiple design options with different degrees of access to internal control variables. The final user could select what provides the best combination of performance and implementation cost. Indeed, it is also critical that the addition of new features like the inertia support does not disrupt already existing and validated functionalities.

This part will focus on developing a set of possible implementation schemes providing functional inertia support in various HVDC applications. The schemes will include conventional implementations relying on a PLL (Phase-Locked-Loop) for grid synchronisation as well as control designs based on emerging control concepts that do not rely on PLL. For example, inertial response can be obtained by modifying only the active power references to an HVDC terminal based on a frequency derivative. This solution can be relatively easy to implement, also in existing HVDC converters, and could provide a slow and simple inertia support. Such a scheme will have functional limitations, since islanded operation or black start of a portion of the grid will not be feasible without a dominant presence of synchronous generators. Furthermore, stability problems caused by the PLL when HVDC terminals are operated in weak grids might be amplified by the use of the frequency derivative and the delays in the practical implementation.

Control strategies that are not relying on a PLL for grid synchronisation could theoretically ensure better and faster performances, but will usually require more radical and intrusive changes to the conventional control systems. Proposed implementation systems (Virtual Synchronous Machine Power synchronisation control, synchronverters, etc.) will be assessed and adapted with respect to implementation in HVDC converter control systems under various constraints, and relevant improvements suitable for implementation in MMC (Multilevel Modular Convertor) HVDC links will be proposed.

A first analysis of the various implementation schemes will be based on a time-domain simulation with a commercially available electro-magnetic transient (EMT) software (PSCAD or EMTP-RV). Then small-signal models (e.g. linearized state space models) will be derived in order to extend the possibilities for mathematical analysis of the stability properties and dynamic performances depending on operating conditions and various parameters in the system. The main results from the work package part will be documentation of the implementation schemes and an assessment of their features, as well as guidelines on the tuning under various conditions. The assessment of dynamic performances will be also relevant to provide feedback to some of the studies in part 1.

The analysis will be extended to several converter topologies including 2L VSCs, MMCs and conventional thyristor-based LCC HVDC schemes. Furthermore, the PhD student at L2EP will focus on implementation and analysis of inertia support schemes in MMC-HVDC interconnections operated in close proximity to LCC HVDC schemes. These studies will consider both independent control of the interconnectors as well as coordination of inertia provision and primary frequency response.

Part 3. Impact of HVDC inertia support schemes on dynamics and stability of large-scale power systems

__Objective:__ Develop new techniques and tools for accurately assessing small- and large-signal stability in large-scale power systems with inertia support from HVDC transmission schemes.

- Task 3.1: System modelling and time-domain simulation of different implementation schemes in a large-scale power system;
- Task 3.2: Small-signal modelling and evaluation of dynamic characteristics and system stability with different implementation schemes;
- Task 3.3: Post-doc at NTNU (Prof. Fosso).

Power systems including power converters translate into large and numerically stiff dynamic systems that can be challenging to solve effectively, both in the time-domain and in the frequency-domain. This work package part will extend and combine the results of the Work package part 1 and work package part 2 by providing a system-level analysis while preserving a detailed representation of the converter units and their associated control. A methodology for detailed verification of power system operation and stability with the investigated HVDC inertia support schemes will be established, including application of dedicated models for representing MMC HVDC terminals that are currently not available in commercial software tools for power system stability analysis. The methodology should also be applicable to analysis of HVDC-connected offshore wind farms. Potential interactions between the HVDC converters and the network leading to resonances and poorly damped or even unstable modes should be identified. The approach can be to extract a relevant part of the reference networks defined in Work package part 1 to be modelled in detail (e.g. frequency dependent models of cables and transmission lines, detailed model of HVDC stations and relevant generation or load nodes) while representing the remaining with a Frequency Dependent Network Equivalent (FDNE). The analysis will be conducted both in the time-domain and with a small-signal model in the state-space.

An additional possibility that will be explored is the application of hybrid electrical models where a part of the network is simulated with an algebraic phasor representation, while the parts where relevant dynamics are expected are modelled by dynamic state-space equations. The post.doc candidate associated with this part of the work package will especially focus on numerical techniques for system analysis, including the integration of detailed HVDC models in the calculation of system eigenvalues and parameter sensitivities in large-scale power systems.

Part 4. Laboratory demonstration

__Objective__: Demonstrate virtual inertia control in a laboratory environment, targeting TRL 4/5.

- Task 4.1: Demonstration of the most relevant inertia support implementations in relevant laboratory-scale grid configuration
- Task 4.2: Laboratory demonstration of inertia support implementations connected to a grid emulator running a power system model in real time

This part aims to provide experimental validation and support to the results obtained in Parts 2 and 3. A first level of validation will be obtained by testing a few selected implementations on a single unit. This will simplify the level of testing by excluding interaction within the control system of a single converter unit. The experimental testing will be further enhanced by realising an experimental setup with several units acting as HVDC terminals with inertia support. The experiments will be conducted in the National Smart Grid laboratory jointly operated by SINTEF and NTNU. The facility includes a flexible infrastructure with reconfigurable electrical buses and several power converters (20-kW or 60-kW units with two-level or MMC topology). A 200-kW grid emulator with a large bandwidth can be controlled to represent electrical transients with a high level of accuracy. The converters and the grid emulator are controllable by two OPAL-RT platforms executing in real time both the control algorithms for the actual hardware and the simulation of grid dynamics provided by the grid emulator. An example of a possible setup is displayed in the figure 32. The approach can be similar to what is described in Part 3, where part of the network is reproduced by a network equivalent or a phasor representation in real time via the grid emulator, while a smaller section is reproduced with real converters and circuit elements. The main objective is to provide a laboratory scale validation of the concepts in an environment close to the real operating conditions and thus to increase the TRL to 4/5.

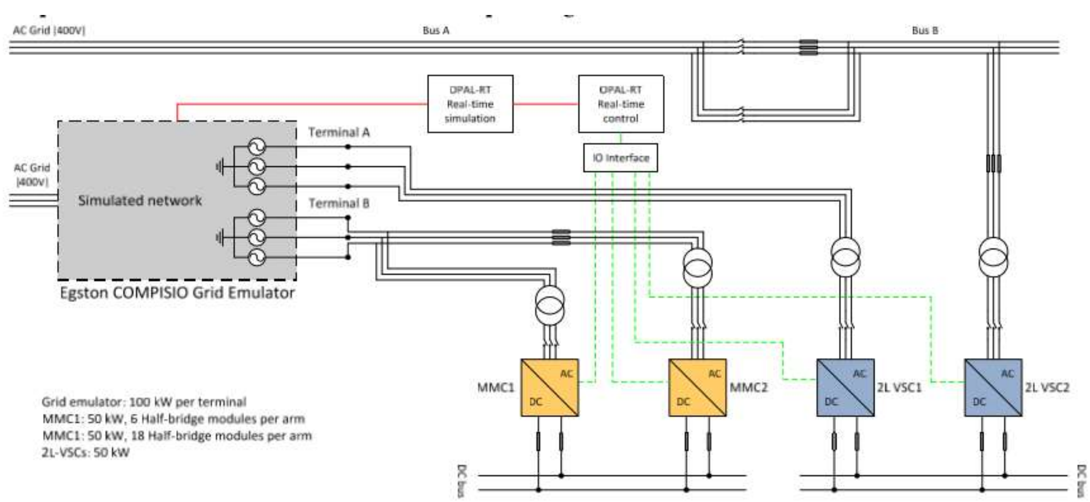


Figure 32 – Diagram showing a laboratory demonstration testing HVDC inertia provision

WP 3. InnoDC

First year ([redacted]):

- General objective: Study of the theoretical limitations of phasor-based representations.

- <u>Specific objectives</u>
  - Literature review on phasor-based models of electrical components used in transient stability programmes;
  - Familiarisation with the power system analysis software PowerFactory;
  - Development and analysis of reduced-order model from a detailed black box converter model on PowerFactory;
  - Implementation of VSC models on MATLAB/Simulink with and without quasi-stationary phasor simplifications to better understand the modelling limitations of the phasor-based approach;
  - Analysis of the frequency behaviour of the models implemented on MATLAB in order to understand how different converter models and inclusion or not of certain control loops can affect the accuracy of the results obtained;
  - Implementation of a test case to understand the behaviour of the models in weak grids.

Second year [redacted]):

- <u>General objective</u>: Study the AC system stability in power systems with single and multiple large converters embedded into the AC system.
- <u>Specific objectives</u>
  - Analysis of the accuracy of the VSC models to represent stability issues in weak grids considering the small-signal behaviour of the system;
  - Extension of the previous analysis by considering the impact of limit-cycles in the accuracy of the models using time-domain simulations;
  - Literature review on control interactions between large converters embedded in the AC system;
  - Test-case implementation of two large converters and analysis of the impact of phasor-based representations considering the small-signal behaviour of the models;
  - Study of the impact of limit cycles on the representation of stability issues due to converter interactions.

Third and fourth years [redacted]):

- <u>General objectives:</u> Study the AC system stability in geographically concentrated power electronics-interfaced wind farms and develop a screening methodology to assess the risk for converter interactions.

- <u>Specific objectives</u>

  - Develop an aggregated (reduced order) system model for several converters in large offshore wind farms. These seek to aggregate several converter characteristics in reduced order models for different AC system

studies;
- Benchmark results with test cases including HVDC and/or large offshore wind farms;
- Develop a screening methodology to assess the risk for converter interactions and provide indicators to possible accuracy issues when using phasor-based models;
- Develop guidelines on how to model the power system for different system studies considering the limitations of phasor-based models;
- Writing the thesis.

Planning by work package

Studies on the impact of HVDC connections and the role they may plan in handling inertia will pile up in the years ahead.

WP 1: Local inertia

The project still needs to be started. The researcher on the first part is no longer available to start this second part. This means we now need to hire a new researcher in collaboration with a university. Therefore the project will only start in [redacted].

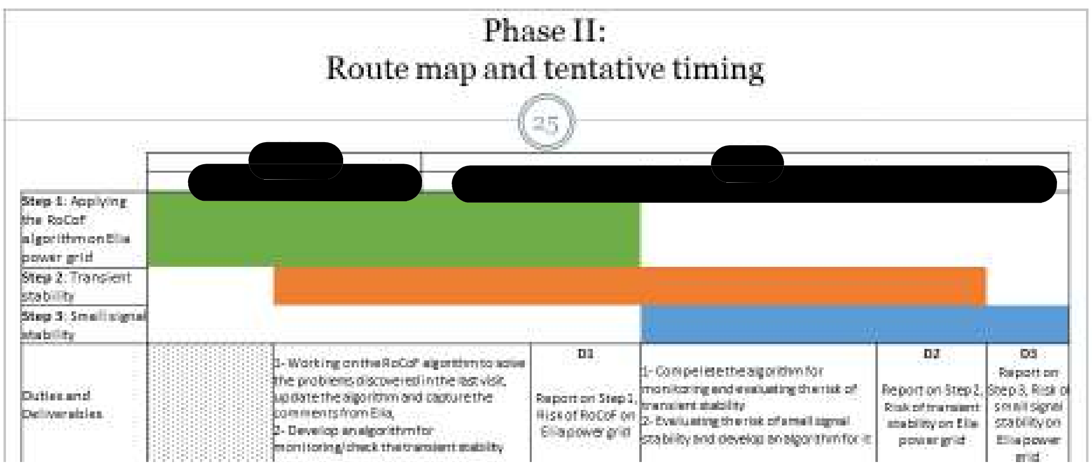


Figure 33 – Planning of local inertia project

WP 2: HVDC Virtual inertia provision

6. Key milestones

The project is estimated to run from the middle of 2017 to mid 2021, as indicated by the project timeline with main milestones and corresponding deliverables shown in the table below:

Milestones and preliminary project schedule

(R: technical Report, M: project Memo, J: Journal publication, C: conference publication, D: laboratory demonstration, T: PhD Thesis, S: Steering Committee Meeting, W: workshop/seminar, P: Planning and financial report)

Project periode	[redacted]		[redacted]				[redacted]				[redacted]				[redacted]	
Activities/Deliverables	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2
WP0. Project Management	P_1		P_2				P_3				P_4				P_5	R_1(*)
WP1 Feasibility and benefit analysis			M_1	M_2	M_3	C_1		$\mathbf{M_4}J_1$								
WP2 Control design and interface				C_6	M_5		M_6		C_7	M_7J_4						
WP3 System stability								M_8	C_{12}	M_9	J_7			$J_8\mathbf{M_{10}}$		
WP4 Laboratory demonstration								C_{15}	D_1	M_{11}				M_{12}	$\mathbf{D_2}J_{15}$	
PhD KU Leuven, (WP1)					C_2		C_3		C_4J_2	C_5			J_3			T_1
PhD L2EP (WP2)				C_8		C_9		C_{10}	J_5		C_{11}	J_6	T_2			
Post.doc. NTNU (WP3)								C_{13}	C_{14}	J_9	J_{10}					
Steering committee meetings	S_1		S_2W_1		S_3W_2		S_4W_3		S_5W_4		S_6W_5		S_7W_6			S_8W_7
Mid-term evaluation																
Secondary Objectives Achievement								1						2,3	4	

(*) Final report to RCN and partners

Results will be also available in interim reports and presentations not indicated in the time plan for brevity. A more detailed plan for reporting, publications, management and meetings will be defined in agreement with the partners in the start-up phase of the project (P_1).

Figure 34 – HVDC virtual inertia provision

[redacted]

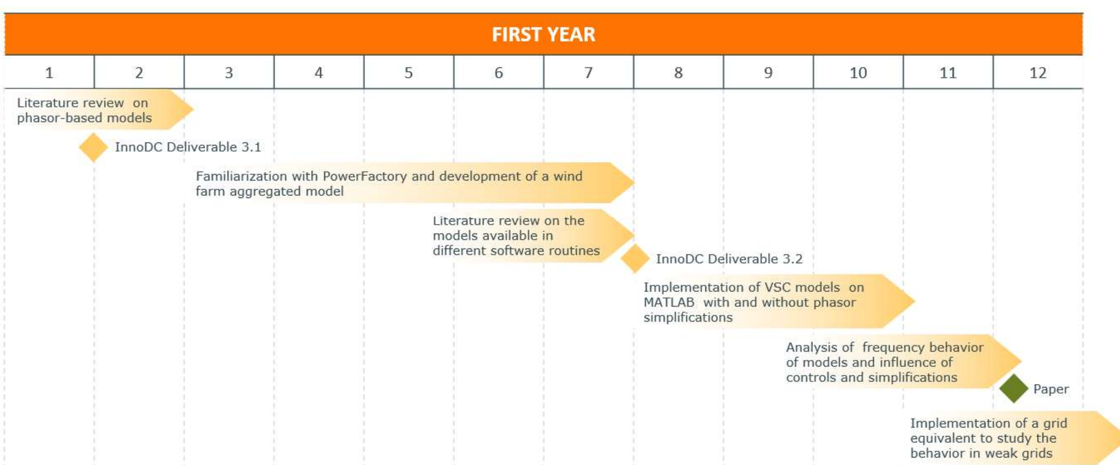


Figure 35 – Detailed planning of HVDC - first year

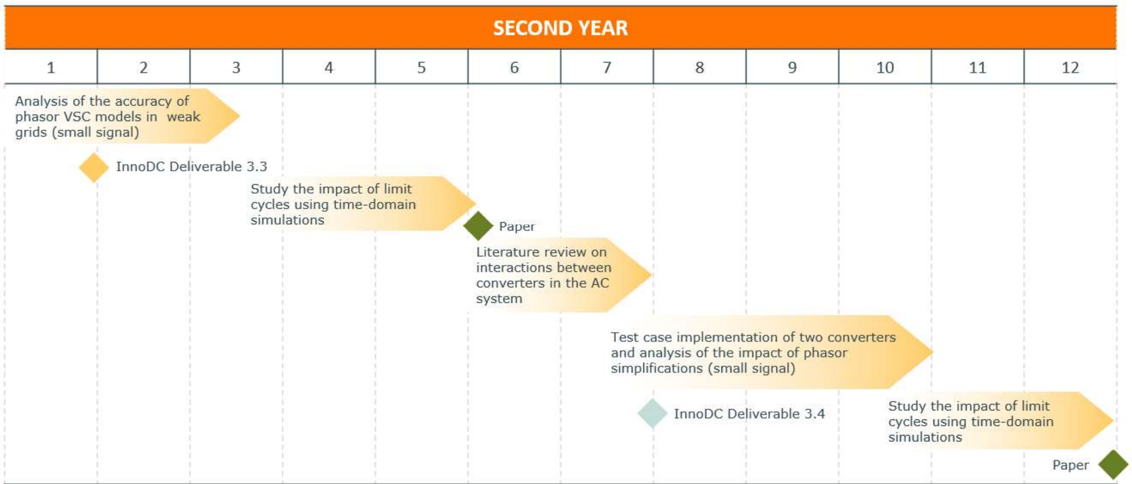


Figure 36 - Detailed planning of HVDC - second year

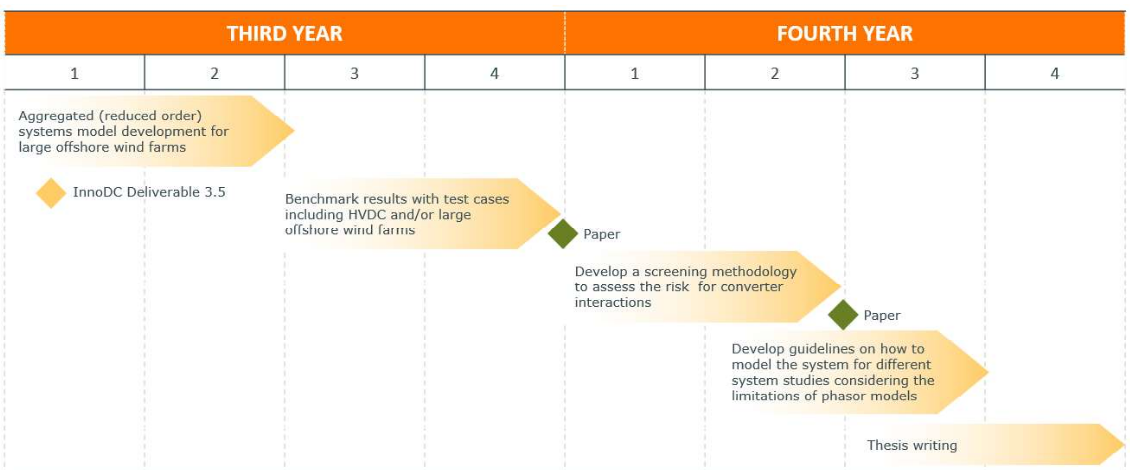


Figure 37 - Detailed planning of HVDC - third year

C. Context/stakeholders in the project

As part of this project, several stakeholders are mandated to conduct research in collaboration with Elia.

WP 1: Local inertia

The first part of Work Package 1 was carried out with Brunel University London (BUL) in 2018-2019. This university hired a post-doctoral research assistant who, at Elia's request, worked full time on this project. Other university and Elia staff supervised this assistant (a principal investigator and a co-investigator). This project was financed by the Belgian federal government's energy transition fund for the years 2018-2019.

For the rest of this project, we will need to find another assistant as the research assistant who has worked on the project up to now has withdrawn for personal reasons. In this part of the project, close consultation with the Elia teams will be needed. Therefore, we will be commissioning a Belgian university (probably KU Leuven) to supervise the research assistant and supply the theoretical and academic knowledge required for the project. The Elia teams will continue to provide monitoring and supervision for the operational application of the research to the Belgian electricity system.

WP 2: HVDC inertia provision

For this work package, Elia has joined a consortium coordinated by SINTEF. SINTEF is Scandinavia's largest independent scientific research organisation (https://www.sintef.no/en/). The consortium is made up of the following stakeholders:

- [redacted]

The industrial partners oversee and co-fund the research.

WP 3: InnoDC

For this work package, Elia has joined a consortium coordinated by Cardiff University (https://www.cardiff.ac.uk/). The members of this consortium are:

- [redacted]

- Danmarks Tekniske Universitet (DTU)
- Katholieke Universiteit Leuven (KU Leuven)
- CG Holding Belgium NV (CG)
- Elia System Operator (Elia)

Each consortium member hosts one or more student researchers. There are 15 students in all.

Elia is working closely with KU Leuven on this project as this university is providing academic supervision of the PhD student hosted by us.

InnoDC is funded by the European Union's Horizon 2020 research and innovation programme, [redacted]

Link to the website for this work package: https://innodc.org/

D. Value development plan

How the project contributes to the strategic objectives

This project intrinsically contributes to supporting the energy transition as it studies the impacts of the penetration of power electronics as well as the integration of renewable energy into the current electricity grid. These studies will help to justify certain European grid-code requirements. As well as studying the impacts and effects of this penetration, it produces solutions that can be applied to the Elia grid.

These studies will make Elia better equipped to handle the day-to-day management of network stability and also to respond in case of an accident, and more efficient in doing so. This is because the models that are developed and the understanding of these will enable us not only to better plan the flows transiting through our grid but also to respond more quickly to an inertial or power electronics-related problem in the grid.

Link with Elia's other innovation objectives

This project focuses mainly on the following innovation objectives:

- Ensure a secure, reliable and efficient grid
- Deliver the transmission infrastructure for the future
- Evolve the system and markets

Indeed, the purpose of this project is to ensure that we keep the grid secure, reliable and efficient whatever happens and this include the penetration of power electronic and as well as potential redistribution of inertia wind farms in the sea, nuclear phase out, etc).

The infrastructure of the future needs to be able to integrate all renewable and all type of production units (from different size to different production means). This can only be done by using technologies that were not yet used today and that might have an impact on the operation of the grid. As the grid was not initially designed for such a change, this poject aims at responding to some question a system operator might have when it comes to integrating such technologies as HVDC, change of inertia dispersion, etc.

It also contributes to make the system and markets evolve in the sense that if we cannot ensure that from a technological perspective the evolution needed by the energy transition and all the new technologies can be integrated, the system as we know it today will not comply for new market. Those can of researches are pre-request to any system and market evolution.

Publication

As the three work packages are linked to academic studies, multiple publications are linked to the related work.

- **Local inertia**
    - A paper was published and presented at the IEEE PowerTech conference in Milan (https://attend.ieee.org/powertech-2019/).

- **HVDC inertia provision**

  - Francesco Palombi, Salvatore D'Arco, Atsede G. Endegnanew, Luigi Piegari, Jon Are Suul, "Impact on Power System Frequency Dynamics from an HVDC Transmission System with Converter Stations Controlled as Virtual Synchronous Machines" in *Proceedings of the IEEE PowerTech Milano, Milan, Italy, 23-27 June 2019, 6 pp.* *https://doi.org/10.1109/PTC.2019.8810855*
  - Gilbert Bergna-Diaz, Jon Are Suul, Erik Berne, Jean-Claude Vannier, Marta Molinas, "Optimal Shaping of the MMC Circulating Currents for Preventing AC-side Power Oscillations from Propagating into HVDC Grids" in *IEEE Journal of Emerging and Selected Topics in Power Electronics*, Vol. 7, No. 2, June 2019, 1015-1030, https://doi.org/10.1109/JESTPE.2019.2894677
  - Javier Roldán-Pérez, Jon Are Suul, Salvatore D'Arco, Alberto Rodríguez-Cabero, Milan Prodanovic, "Virtual Synchronous Machine Control of VSC HVDC for Power System Oscillation Damping" in *Proceedings of the 44th Annual Conference of the IEEE Industrial Electronics Society*, IECON 2018, Washington D.C. USA, 21-23 October 2018, pp.6026-6031, https://doi.org/10.1109/IECON.2018.8591097
  - Gilbert Bergna-Diaz, Julian Freytes, Xavier Guillaud, Salvatore D'Arco, Jon Are Suul, "Analysis of MMC Dynamics in DQZ Coordinates for Vertical and Horizontal Energy Balancing Control" in *Proceedings of the 44th Annual Conference of the IEEE Industrial Electronics Society*, IECON 2018, Washington D.C. USA, 21-23 October 2018, 8 pp. 5999-6006, https://doi.org/10.1109/IECON.2018.8592881
  - Jon Are Suul, Salvatore D'Arco, "Comparative Analysis of Small-Signal Dynamics in Virtual Synchronous Machines and Frequency-Derivative-Based Inertia Emulation" in *Proceedings of the 18th International Conference on Power Electronics and Motion Control*, PEMC 2018, Budapest, Hungary, 26-30 August 2018, pp. 344-351, https://doi.org/10.1109/EPEPEMC.2018.8522010
  - Gilbert Bergna-Diaz, Julian Freytes, Xavier Guillaud, Salvatore D'Arco, Jon Are Suul, "Generalized Voltage-based State-Space Modelling of Modular Multilevel Converters with Constant Equilibrium in Steady-State" in *IEEE Journal of Emerging and Selected Topics in Power Electronics*, Vol. 6, No. 2, June 2018, pp. 707-725, https://doi.org/10.1109/JESTPE.2018.2793159
  - Salvatore D'Arco, Giuseppe Guidi, Jon Are Suul, "Operation of a Modular Multilevel Converter Controlled as a Virtual Synchronous Machine" in *Proceedings of the International Power Electronics Conference*, IPEC 2018 ECCE Asia, Niigata, Japan, 20-24 May 2018, 8 pp., https://doi.org/10.23919/IPEC.2018.8508009

- **InnoDC**

  - Innovative tools for offshore wind and direct current grids (InnoDC), “Deliverable 3.1: Report on the review and evaluation of DC and AC grid operation and interactions in different time frames”, Aug 2018. Available at: https://innodc.org/wp-content/uploads/sites/11/2019/03/Review-and-evaluation-of-DC-and-AC-grid-operation-and-interaction-Aug-2018.pdf

- Innovative tools for offshore wind and direct current grids (InnoDC), "Deliverable 3.2: Report on dynamic converter interactions and the feasibility of different software routines to represent the problems", Feb 2019. Available at: https://innodc.org/wp-content/uploads/sites/11/2019/03/Dynamic-converter-interactions-and-different-software-Feb-2019.pdf

- C. Nathalia, Simulation of power systems for transient stability studies, 29 August 2019. [Streaming video]. Available at: https://www.youtube.com/watch?v=0nEY189CMfk

Implementation plan

The implementation phase will come right after the results of the studies and when the results are known. In term of implementation, we can see it from different angles:

- First we can already implement the knowledge created by the researcher during their work to use it during discussion within technical committees;
- When it comes to the integration of models, those models will be directly usable in our simulation tools and will therefore be immediately implemented;
- For the solution that requires a bigger integration (like new assets, etc), the implementation will be taken into consideration in the grid development activities.

12. ASSESSING THE ROLE OF BVLOS DRONES FOR LINE INSPECTION

A. Innovation objective & problem to solve

Problem definition

One of the main activities of a TSO is to operate and maintain power transmission lines within its own network infrastructure.

The electricity grid is built with different technologies, most of which have specific electricity pylons and other components as isolators, conductors or fittings. E.g. typical pylon shapes characteristics can be:

- two superimposed trusses, usually the narrower one at the top;
- three superimposed traverses. The middle cross beam is the widest, resulting in the typical barrel shape;
- at least two supports that promise great stability but require more space,
- the conductor traverse sits on a V-shaped fork;
- the largest traverse is at the bottom, the second largest in the middle and the smallest at the top, resulting in the typical fir tree shape.

In parallel lines needs also to be inspected.

As a result, maintenance activities and inspections are carried out regularly and are very complex due to the different technologies mentioned above. No matter how the technologies of overhead lines will change in the future, the need for regular inspections will remain. In accordance with legal framework electricity network operators are legally obliged to ensure "a safe, reliable and efficient energy supply network" with regard to maintenance and operation. After all, steel lattice masts have a service life of around 80 to 100 years.

Today, the need of maintenance activities is generally identified by technicians and engineers who inspect the lines at source once or twice a year. The overhead lines are mostly inspected by observation from the ground using binoculars or by climbing. Several preliminary tests were carried out with helicopters equipped with multi-camera systems. However, helicopter inspections are very expensive.

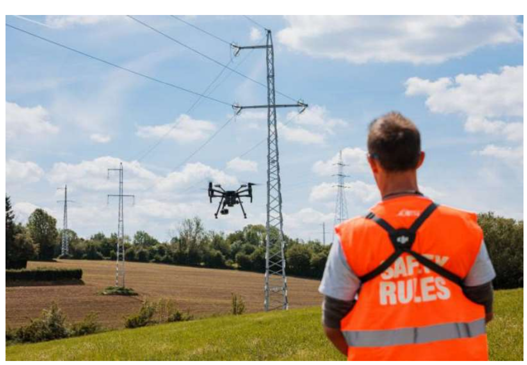


Figure 38 – Drone pilot

Another approach to assessing the condition of the line is to fly over the corridor with drones connected as Unmanned Aircraft Systems (UAS) flying from the field of view. Depending on the grid, electricity pylons have an average height of about 22 m for 110 kV lines and 83 m for 380 kV lines. During these inspections, special attention is paid to each of the single components as well as to vegetation in the respective corridor. This usually requires an ascent by climbers. Climbers must always be secured by a second person. A drone provides a clear remedy here, as climbing on the power pole is no longer necessary for pure inspection. It is only necessary to climb onto the masts that have actually been found to have damage that can be repaired. Therefore it is planned to implement drone operation in inspection teams.

Today, different use cases with pilots operating the drones (VLOS) are planned to be implemented. VLOS (Visual Line Of Sight) characterises the drones mode operated by a pilot. The pilot remains at all time on visual line of sight to the drone.

Figure 39 – Example of drone use for inspection (VLOS)

The following use cases are currently considered to be implemented in Elia in 2020/2021.

1. **Micro view of components of overhead lines without outages**

   There are several cases where a micro view of necessary, e.g. defect detection during the inspection or assessment of maintenance activities

2. **Inspection of painting work**

   The objective is to increase the quality of painting work by challenging more randomly the performed painting works of service provider.

3. **Commissioning quality control**

   This use cases aims on performing quality checks for tower delivery with drones instead of climbing.

4. **Assessment of incident acceleration**

   The objective is the easier inspection of hard to patrol spans as well as better and faster assessment of the faults.

For all planned activities it is common that the pilot operates the drone reasoning one certain purpose as identifying the defect or planning the respective maintenance activity.

Objective

In contrast to VLOS the focus of the innovation project is aiming to prepare the basis for the autonomous drone operation (BVLOS) as next step for Elia. With the BVLOS (Beyond Visual Line Of Sight) operation mode drones are supposed to fly autonomously along the lines in order, e.g. to measure the temperature distribution using thermal cameras or to collect series of images that will be analysed to identify construction defects.

The connected drones are powered by a modem and a SIM card to be connected to the general mobile connection network (GSM). Compared to helicopters, these devices allow the TSO to carry out inspections with less effort, but also with less impact on the environment.

Figure 40 – Example of pylon inspection using drones

The following BVLOS use cases are currently considered to be researched in Elia.

1. **Helicopter flights**

   The entire grid will be inspected once every three to five years. The helicopter flights are very cost-intensive and may be characterised by high emission levels. The use case investigates substitution helicopter flights by BVLOS-operated drones.

2. **Incident inspection**

   In case of incidents it is important that the inspection will be conducted as soon as possible. The use case investigates substitution helicopter flights by BVLOS-operated drones.

Impact for Elia: KPIs and/or hypothesis (qualitative and quantitative)

In comparison to a classic ascent of a power pole, the drone is significantly faster. On average, it only takes about one third of the time of a climber per power pole, thereby substantially reducing the time required. In perspective, the potential is even greater if the drone can fly independently from one mast to the next. **The target is to increase**

the efficiency on maintenance activities (no quantification available yet).

Secondly, the item addresses the safety targets of Elia. The drone gives you the opportunity to inspect a pylon with a micro view without climbing on the tower. **That is why another target is to increase the safety.**

One important additional aspect is the environmental impact. Due to the fact that long-line inspections today are mainly conducted via helicopters, it is expected that by using drone emissions, will be avoided. **The objective is to reduce the environmental impact.**

Use of the results

The use of the results will be mainly seen in improvements in the following fields:

- efficiency of maintenance activities;
- increase in the safety of maintenance workers;
- reduction in the environmental impact.

The exact quantification is on-going.

B. Project definition and planning

BVLOS drone operation can be divided into four building blocks as shown below.

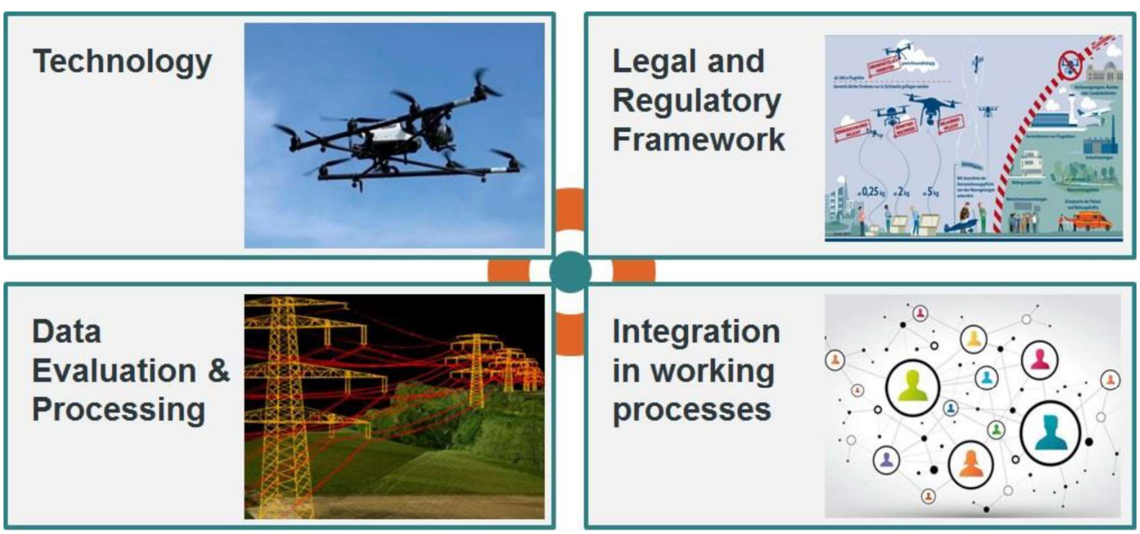


Figure 41 – Main topics to be tackled to assess the feasibility and impact of BVLOS drones

The innovation project focuses on the ***"Technology"*** and ***"Data Evaluation and Processing"*** building blocks. The other two building blocks will be handled outside the innovation project.

For the ***"Technology"*** building block, we will test the following set-up:

- Drones can fly with only 100-km coverage;

- The drones are equipped with multi-camera/sensor systems;
- The drones have portable data storage;
- The recorded data have to be transferred to the IT system after the flights.

The expected assumption to be validated are:

- an increase in the quality of failure detection and vegetation analysis;
- the automation/digitalisation of our infrastructure as a core competence.

For the ***"Data Evaluation and Processing"*** building block, this is the status of the following items in terms of whether they are state of the art:

- Machine learning can be seen as an existing basic technology;
- Object identification is a matter of training;
- Malfunctions are not state of the art;
- No independent algorithm is available; service providers are seeking the Elia Group's participation to train their algorithms.

The following can be viewed as specific impacts:

- an increase in the quality of failure detection and vegetation analysis;
- the automation/digitalisation of our infrastructure as a core competence leading to gains in inspection time and flexibility.

Overall type of the project (innovation phase) and program

Exploration phase

Develop the asset of the future and use connected devices to maximize safety, efficiency and insights

Separation into work packages

As described above for the innovation project, the focus is on the "Technology" and "Data Evaluation and Processing" building blocks. In order to show the planned work packages the two building blocks can be regarded as sub-projects. Additionally, if in future different operators are using BVLOS as an operation mode, it will be necessary to coordinate the respective flights operated by Elia with the flight schedules of other operators. This ***"Coordination of flight schedules"*** use case can be considered a third sub-project.

1. "Technology" sub-project

The "Technology" sub-project will be conducted in order to assess the technical feasibility of BVLOS drone operation mode for Elia.

The following work packages are planned:

- WP 1 Definition of technical research frame;

- WP 2 Definition of the corridor and translation into 3D models;
- WP 3 Definition of scenarios for the BVLOS drone operation mode;
- WP 4 Technical tests;
- WP 5 Validation and interpretation of results.

3. "Data Evaluation and Processing" sub-project

The "Data Evaluation and Processing" sub-project will be conducted in order to assess the feasibility for Elia of AI-supported monitoring of energy transmission systems by aerial drones.

The following work packages are planned.

- WP 1 Definition of data standards, database structure;
- WP 2 Development of AI algorithm;
- WP 3 Generation of images of components and the respective defects;
- WP 4 Labelling of the determined images and translation into data sets;
- WP 5 Completion of database and structuring of data;
- WP 6 Training of AI algorithm with a training data set;
- WP 7 Testing of AI algorithm with a test data set;
- WP 8 Comparison of results with benchmark and interpretation of data.

4. "Coordination of flight schedules" sub-project

For the "Coordination flight schedules" sub-project, Elia is participating in the European project "SAFIR". The SAFIR (Safe and Flexible Integration of Initial U-space Services in a Real Environment) consortium, a group of 13 public and private organisations, has been selected by Single European Sky ATM Research Joint Undertaking (SESAR JU) to demonstrate integrated drone traffic management for a broad range of drone operations in Belgium.

The objective of the demonstration is to help SESAR JU, the entity responsible for coordinating all EU research and development activity in Air Traffic Management, contribute to the European Commission's U-space vision of ensuring safe and secure access to airspace for drones.

U-space is an enabling framework designed to facilitate any kind of routine mission, in all classes of airspace and all types of environment - even the most congested – while addressing an appropriate interface with manned aviation and air traffic control. When fully deployed, a wide range of drone missions that are currently being restricted will be possible thanks to a sustainable and robust European ecosystem that is globally interoperable. The timing for U-space is critical given the speed at which the market is growing. The aim is to have foundation U-space services in place by 2019.

The SAFIR consortium will perform demonstration that BVLOS drone operations are viable, robust and ready to implement throughout Europe. The goal of the SAFIR project is to contribute to the EU regulatory process for drones and drive forward the deployment of interoperable, harmonised and standardised drone services across Europe. These demonstrations will include surveillance flights (including container terminal inspection, oil spill inspection) in the Port of Antwerp, (medical) parcel delivery, high voltage line mapping and pylon inspection. Furthermore, the use of telecommunication network technology for data communication with both manned aircraft and other unmanned aircraft will be assessed. Finally, a radar system will be deployed capable of monitoring cooperative and non-cooperative drones.

The SAFIR project activities will geographically cover two areas in Belgium. The first area is Sint-Truiden with the Drone Test Centre of DronePort (www.DronePort.eu). The second area is the larger Antwerp area, including the Port of Antwerp.

The following work packages are planned.

1. WP 1 Project planning;
2. WP 2 Assessment of technology by all operators;
3. WP 3 Verification of drone platforms, homologation and organisational items (e.g. pilot licences);
4. WP 4 Drone platform – UTM integration;;
5. WP 5 1. Demonstration Day: DronePort Dry Run
6. WP 6 2. Demonstration Day: Antwerp;
7. WP 7 Finalisation of study report.

Planning by work package

1. "Technology" sub-project

The "Technology" sub-project will be planned in [redacted] and conducted in [redacted]

2. "Data Evaluation and Processing" sub-project

The "Data Evaluation and Processing" sub-project will be planned in [redacted] and conducted in [redacted]

3. "Coordination of flight schedules" sub-project

The "Coordination flight schedules" sub-project will be conducted in [redacted] and the final report will be completed in [redacted]

C. Context/stakeholders in the project

1. "Technology" sub-project

For the “Technology” sub-project, it is planned to cooperate with a technology provider, e.g. a start-up. The choice of the partner has not been finalised yet.

2. “Data Evaluation and Processing” sub-project

For the “Data Evaluation and Processing” sub-project, it is planned to cooperate with an independent partner in order to keep the data sovereignty about the data generated during the project duration. Therefore the sub-project will be conducted with a research institute. The choice of the partner has not yet been finalised.

3. “Coordination of flight schedules” sub-project

As described above for the “Coordination flight schedules” sub-project, Elia is participating in the European project “SAFIR”. The SAFIR consortium consists of the following organisations: Unifly, Belgocontrol, Amazon Prime Air, Proximus, the Port of Antwerp, the Elia Group, SABCA, DronePort, Helicus, High Eye, C-Astral, Tekever and Aveillant.

D. Value development plan

How the project contributes to the strategic objectives

The underlying strategic objective is *“Become a digital utility (assets are monitored and inspections are automated)”*

Data and automation have a substantial impact on the world of tomorrow. To understand the prospects arising from the digital opportunities, we need to embrace these. This requires a deep understanding, achieved by testing the opportunities and prototyping the most promising technologies. This innovation project fulfils the strategic objective.

Link with Elia's other innovation objectives

Further strategic objective:
State-of-the-art (transmission) assets with the least possible impact on society
The development of new assets gives us opportunities to improve our day-toy-day work. We need to step up information flows and knowledge exchange within the Group to focus on the relevant topics and to work efficiently. Additionally, the communication with partner and stakeholder gives us a better understanding of how we can have a minimal impact on the environment at minimal cost while maximising reliability.

Implementation plan

The implementation plan of the innovation project consists of the following items:

- finalisation of the tests described;
- planning the introduction of the BVLOS operation mode into existing working processes;
- adjustment of working processes.

Potential next steps

1. "Technology" sub-project

- Choice of technology provider to specify the technical and organisational framework

2. "Data Evaluation and Processing" sub-project

- Choice of an independent partner to define the data quality and standards

3. "Coordination of flight schedules" sub-project

- Finalisation of the project and documentation of lessons learnt

13. TESTING ROBOTS FOR INSPECTION

A. *Innovation objective & problem to solve*

Problem

The demand for renewable energy is fuelling the development of wind farms in the North Sea. With the proliferation of these wind farms, which are being set up further and further offshore, Elia is playing a key role in interconnecting these facilities to the mainland by means of its brand-new offshore platform, which features a converter substation. Eventually, drawing on additional platforms, Elia's vision is to enable the creation of an offshore grid that will link up the relevant countries' wind farms. This would make offshore power generation stable, thereby averting energy price rises in adverse weather conditions.

However, operating and maintaining such offshore platforms is demanding and resource-intensive. The economic and environmental limitations of offshore operations are a driving force behind minimising these human interventions, given that each planned operation on the platform requires boats to be used, costing a lot of time and money. Therefore, the journey and the lack of space and dangerous environment of the offshore station on the platform make the days long and risky for the operators. Using a helicopter is also a cost and, like the boat, depends on weather conditions. This lack of flexibility is not aligned with the use of renewable energy, which requires a lot of such flexibility due to its intermittent nature. It goes without saying that all the costs mentioned for this new infrastructure will have a direct impact on the price for the end consumer.

Robots may be a solution to these issues because they can perform remote maintenance, thereby offering a flexible tool because of their modularity (replacement/addition of sensors or tools), and can be programmed, unlike fixed sensors.

Unmanned ground vehicles (UGVs) can also meet the requirement level Elia imposes by providing an additional tool for daily inspection (i.e. more frequent inspections). Remote inspection can also be useful to perform quick assessments in an emergency, thereby reducing the power-off time.

Objective

The robot initiative aims to understand UGVs' potential to enable Elia to perform inspections, analyses and even basic actions as the case may be:

- in remote areas, offshore platforms are the main use case;
- in areas that are hazardous or where time is needed before any potential human intervention (e.g. HVDC substation generating a substantial magnetic field).

This initiative should allow Elia to evaluate the handling and abilities of robots in real conditions.

In practice, the project will aim to understand the following questions:

- How can robots be handled in the context of a substation?
- What are the technical and physical limitations of operating a UGV?
- What are the maintenance and upgrading needs/opportunities?

To this end, three use cases have been identified for the application of robots in substations. These are illustrated in Figure 42.

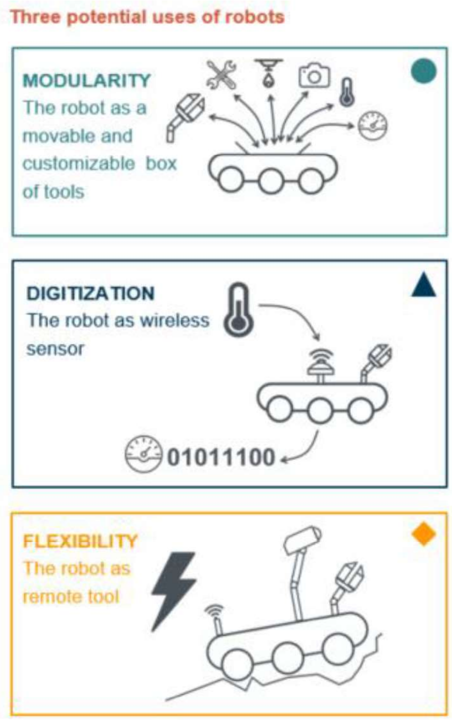


Figure 42 – Use cases for robots in substations

Impact for Elia: KPIs and/or hypothesis (qualitative and quantitative)

There are many impacts for Elia, covering the following aspects, as shown in the figure below: sustainability, reliability, profitability, reputation and safety. These assumptions are described in the table in Figure 43.

Impact of robot	SUSTAINABILITY	RELIABILITY	PROFITABILITY	CORPORATE IMAGE	SAFETY
• Easy replacement and upgrade					
- Easy defect equipment replacement | *no need to replace all the robot*	●		●		
- Access to latest and expensive sensors technologies		●	▲		
• Offsite maintenance | *No outage required*		●	●		
• Scalability | *One robot for many assets*	●		●		
• Scalability | *Application of the technology to other sites*	▲		▲		
• Innovation and investment in new technologies				▲	
• Easy and fast deployment		▲	▲		
• Assets integrity improvement | *Enabled through more frequent inspections*		▲			
• Travels avoidance	◆		◆		◆
- Faster intervention | *Remote inspection and operations*		◆			
• Remote operations on dangerous environment					◆

Figure 43 – Robotics' potential impacts

The profitability assumptions for the offshore-platform case are based on two scenarios:

1. **Day-to-day activities:**
    a. The robot's impact on the efficiency of operations. This should improve preparations before maintenance tasks, thereby reducing the time on site and/or the number of tasks per year;
    b. By reducing the number of maintenance tasks, journeys by boat or helicopter, which are very expensive, will be avoided.
2. **Emergency scenarios:**
    a. The robot can perform an accurate assessment (e.g. find the source of a gas leak) and reduce the decommissioning time. The main costs avoided are fines.

These potential benefits constitute **assessment criteria** for the use of robots. If none of them is positive, the scenarios for use of robots will have to be changed for the platform or planned on other sites.

Use of the results

Supporting the energy transition						
Improving public acceptance						
Boosting Elia's efficiency levels						
Enhancing market design						

The implementation of UGVs at the substations, and in particular in conditions such as the offshore platform, will reduce response times and streamline the work and the need for operators to visit these, avoiding unnecessary travel.

As mentioned above, the use of renewable energy means using new transport technologies. The growth of these more 'exotic' assets, such as HVDC conversion substations, AC cable tunnels and offshore platforms, brings to light a new working method that brings with it new operational constraints. The introduction of UGVs into these assets would provide a solution for some of these problems, such as the time, cost and planning needed to perform basic operations on an offshore platform, not to mention the inaccessibility of narrow tunnels. Their benefits here are that they eliminate the direct risk of injury to workers and enable the relevant (basic) operations to be performed at remote sites from almost anywhere.

B. Project definition and planning

Overall type of the project (innovation phase) and program

Exploration phase

Develop the asset of the future and use connected devices to maximize safety, efficiency and insights

Separation into work packages

The project has the following phases:

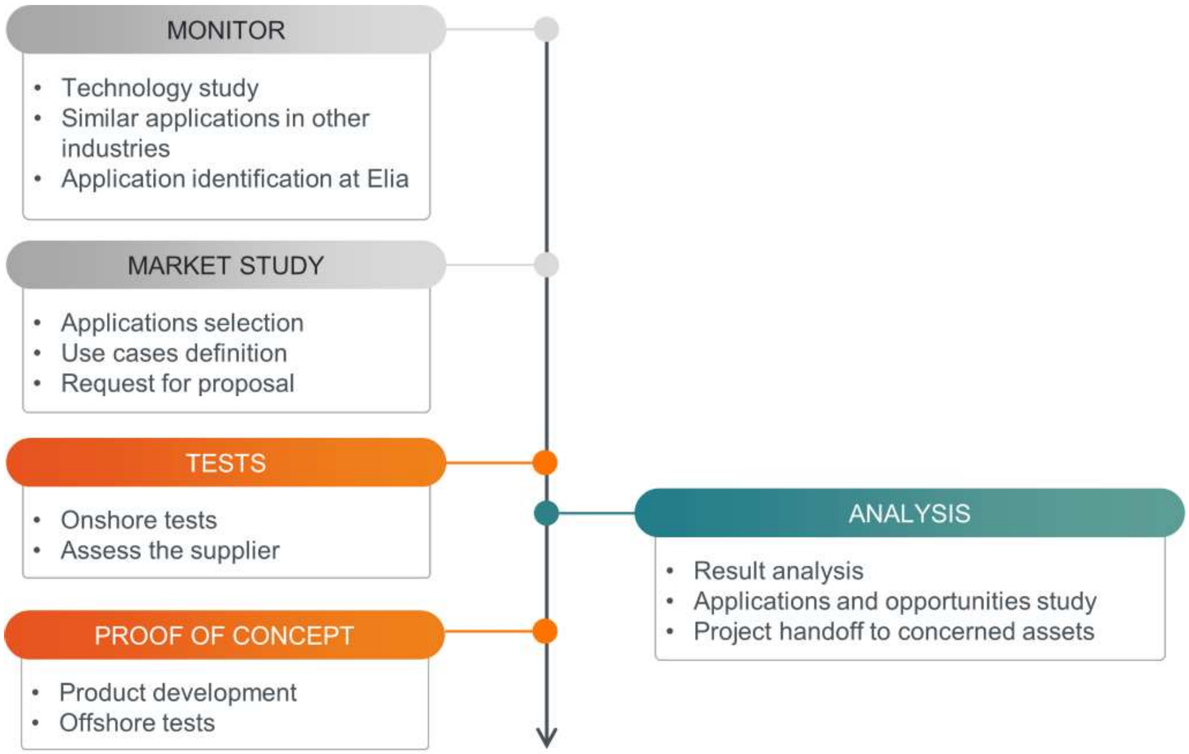


Figure 44 – Phases of the robotics project

The project consists of five phases. Two of them, relating mainly to analyses, have already been implemented:

1. **Monitoring:**

The purpose of this phase was to discover the relevant technology by identifying robots' maturity, capabilities, prices and use cases. This was achieved through various channels: a workshop, robotics trade fairs, a review of the scientific literature and a partnership with an engineering school (ECAM) involving a final dissertation being written about this subject. This information was brought together with Elia's needs in a study and a workshop to determine potential use cases in the company.

2. **Market study:**

Once the potential applications had been identified, the most beneficial one for Elia has been determined taking into account robots' capabilities in the current market. This application, namely the MOG (offshore platform), will be the subject of a proof of concept.
This followed the description of the various use cases (scenarios) as well as the technical specifications with a view to launching a call for tenders. The preliminary market study involved consulting nine potential suppliers, six of whom responded. After evaluating the price quotes, three suppliers were selected based on the following criteria:

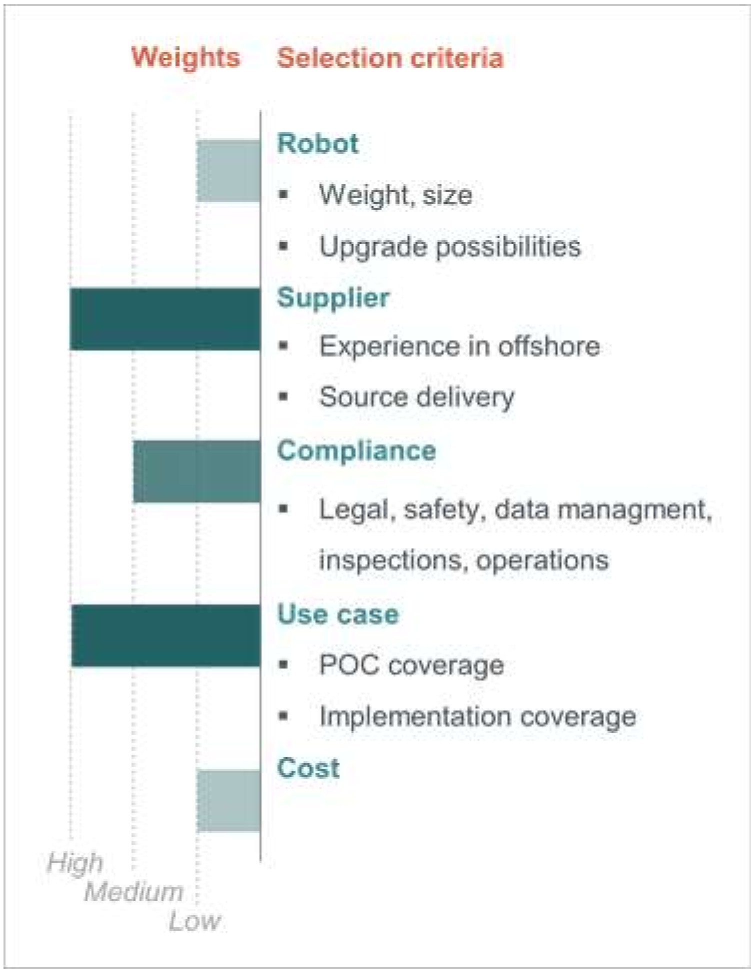


Figure 45 – Robot supplier selection criteria

The POC coverage criteria are the six use cases identified in connection with the MOG. At the time of writing, three phases remain, namely the Testing, POC and Analysis phases. These three phases are described separately as a work package below.

3. **Testing:**

Before launching the offshore proof of concept in real conditions, tests will be conducted onshore under similar conditions to avoid logistics cost of the offshore platform. These tests will be performed using existing products offered by the suppliers and have a number of objectives:

- Evaluate the three suppliers and determine who will carry out the proof of concept. Selection will be based on the criteria used for selection during the market study, with the difference that there will be more scenarios evaluated and they will be more specific;
- Establish scenarios to be used in the offshore POC;
- Determine the changes to be made in the technical specifications;
- Determine the developments to be carried out on the robot by the supplier selected for the POC.

4. **Proof of concept:**

The results of the tests will allow the selected supplier to tailor its product appropriately for the proof of concept. Period in which there will be iterative work between the development of the scenarios in the POC (Elia's side) and the adjustment of the prototype (supplier's side).

Once they have been launched, the offshore test scenarios will be divided into two parts:

1. the first part will focus on manual control of the robot and compliance with the specifications;
2. the second part will focus on the autonomous part (data collection and processing) and remote checking.

The aim is to carry out these tests by requesting the minimum possible resources while spacing them enough over time for them to proceed under different conditions and to ensure that sufficient data are collected. The first part will be taken care of in one or two intensive sessions by calling on input from all the parties involved while the second, more autonomous part will take place over several months and be staggered over relatively substantial intervals.

The aims of the proof of concept are to:

- assess the technology and demonstrate the feasibility;
- confirm the anticipated profit potential based on KPIs.

5. **Analysis:**

This will be followed by analyses that will determine whether or not industrialisation is beneficial. These results will also be used to evaluate other potential applications (substation, HVDC conversion hall, etc.).

In this process of implementation on other sites, the plan is to use the MOG, whose integration of robots provides considerable added value, to reduce the cost of mastering the technology.

The analysis phase is considered as a separate work package because it will take place at the same time and will require special resources (an expert in the relevant field, a workshop, exchanges with suppliers, etc.).

Planning by work package
The study and market analysis were conducted in 2019, while the testing and POC phases will follow the schedule set out in the table below.

	Test phase	POC phase
[redacted]	Preparation with the selected suppliers	Definition of test scenarios
	On-shore testing	Analysis of the results of the first phase
	3 three-hour sessions	Manual control tests and compliance with the specifications (environment)
		2 test sessions on the platform with staff
[redacted]		Autonomous operation tests
		Autonomous data collection and remote check

C. *Context/stakeholders in the project*

Many parties were consulted to identify potential suppliers and applications.

To start with, an analysis of the applications already existing in other industries (both the energy sector and other sectors) was conducted: the defence, transport and energy sectors (Total, TenneT, CEA, Shell, State Grid Corporation of China, Red Eléctrica de España, etc.).

These analyses as well as the market analyses led to potential suppliers, who are players on the current market. Given that we are not experts in robotics, work was carried out in close collaboration with them to identify potential applications. [redacted]

The same potential suppliers were consulted as part of a *request for proposal* with a view to implementing the POC), namely:

[redacted]	[redacted]	Spain
[redacted]	[redacted]	USA
[redacted]	[redacted]	USA
[redacted]	[redacted]	Austria
[redacted]	[redacted]	Netherlands
[redacted]	[redacted]	France
[redacted]	[redacted]	Switzerland
[redacted]	[redacted]	Switzerland
[redacted]	[redacted]	France

Today, three of them have been selected to continue the project, two of whom already have offshore experience.

D. Value development plan

How the project contributes to the strategic objectives

As mentioned in the 'Innovation objective' chapter, this project responds to two main strategic objectives:

1. **Supporting the energy transition**
   The energy transition requires more renewable energy and interconnection infrastructure to address the problem of the intermittent nature of such energy sources. This demands not only new technologies which may involve more 'exotic' infrastructure, like that mentioned at the start of this document, but also more flexibility. Exotic assets bring with them new challenges related to maintenance and the difficulty in accessing them, such as making the sea crossing, the lack of oxygen in the tunnels and overly strong electromagnetic fields in the converter halls required for the international interconnections. Robotics may provide an answer to these new challenges by enabling secure remote access.
   The robots' modularity and ability to be programmed and the fact that they do not have a fixed position means that they provide a high level of **flexibility**, which is an absolutely vital feature of the energy transition.
   This flexibility is backed up by the substantial volumes of data that can be collected by a robot, which in this way contributes to the digitalisation of assets, which is a vector of flexibility.

Finally, more concretely, the use of robots averts the need for journeys with a major carbon footprint.

2. **Boosting Elia's efficiency levels**
The robots' characteristics mentioned above also have an impact on the efficiency and reliability of the network, such as access to the latest technologies (as a result of the robots' modularity) and the ability to take quick action remotely when incidents occur, avoiding the problematic journeys. Specifically, as regards the MOG, a 32-minute helicopter ride is needed to reach the platform in even the best weather conditions, not including the time required to obtain the relevant flight clearance. Unlike fixed sensors, robots' mobility makes it possible to perform maintenance off site without having to switch the power off and the usual robot can be replaced by another one while it undergoes maintenance. This also illustrates how easy it to implement the technology. A second step, once the technology has been mastered properly, will be frequent autonomous inspections, which will provide more asset data.

   Assessment criteria will be established in advance on the basis of the anticipated efficiency gains:
   - **On a day-to-day basis:**
     - Better preparation and assessment;
     - Greater efficiency of maintenance operations;
     - Improved maintenance;
     - Reduction in operations-related journeys.
   - **Emergencies:**
     - Better assessment, and real-time data;
     - Improved efficiency of interventions, limiting downtime.

   These criteria are listed for the MOG but efficiency gains can also be enumerated at other sites based on robots' three main characteristics, namely modularity, digitalisation and flexibility.

Link with Elia's other innovation objectives

The robots test is in line with 2 key building blocks of the Elia strategy:

Delivering the transmission infrastructure of tomorrow:

Currently, four major trends can be discerned in the transformation of the energy landscape:

1. the substantial flows of renewables in Europe;
2. the generation of renewables;
3. decentralisation;
4. digitalisation, which is also in fact the driving force behind the first three trends.

Keep looking out for innovation and for growth opportunities:

Like many innovation projects, the investigation of robots aims to ensure that we stay up to date with the latest available technologies to ensure that our infrastructure is aligned with our future requirements.

Implementation plan:

Five phases were identified to reach the end of the project, the last of which consists of the steps required for industrialisation.

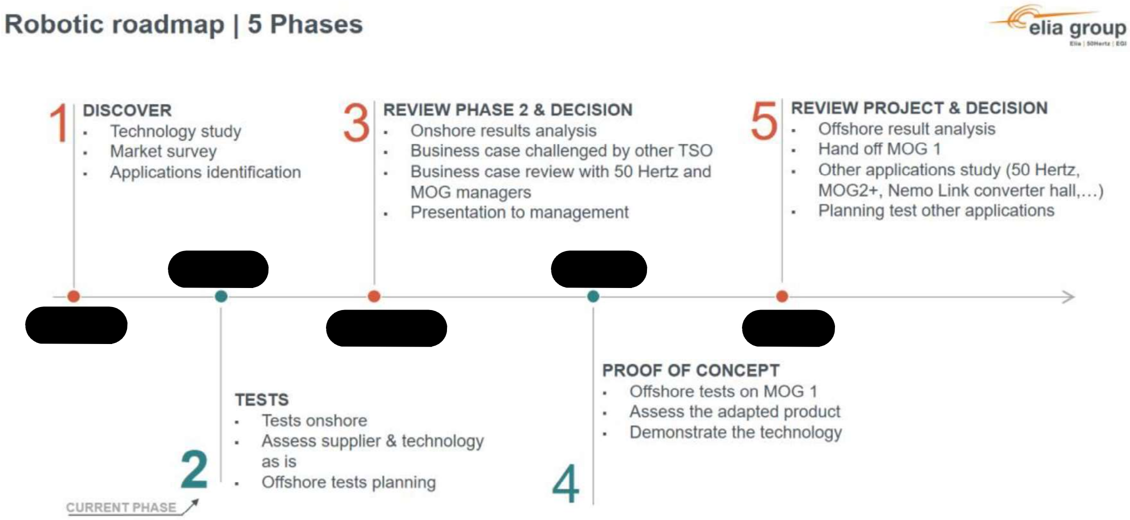


Figure 46 – Phase of implementation of robots in the Elia business

We are currently in the second phase, which is detailed below:

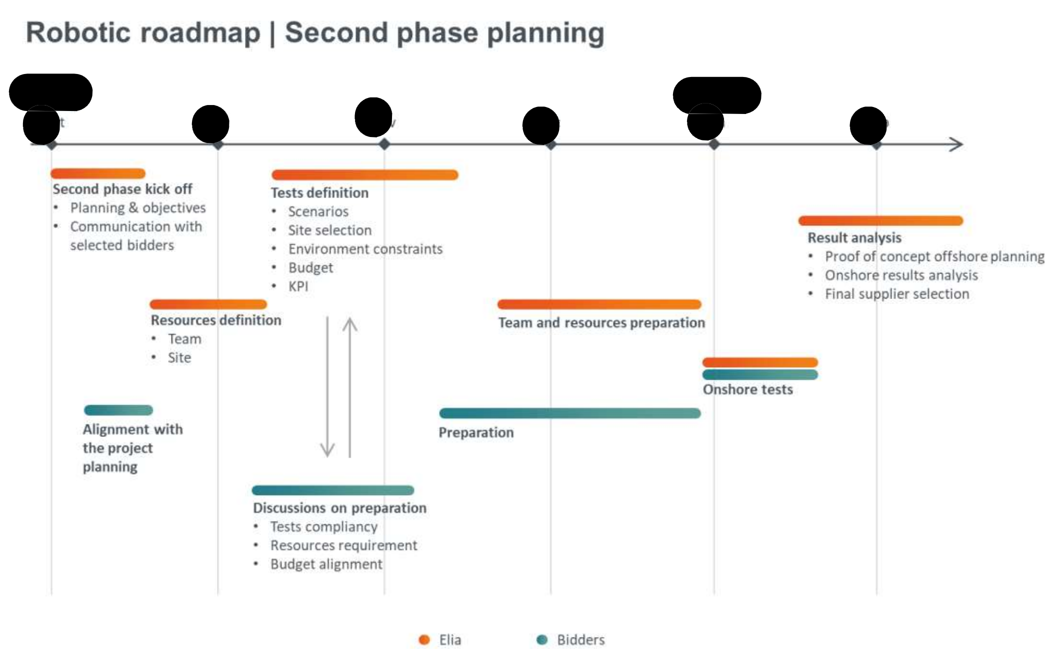


Figure 47 – Details of the second phase of implementation

Potential next steps

- Industrialisation of MOG 1 after validation of the use case/business case
- Depending on the results, analysis of other potential applications in other Elia assets:
    - [redacted]
    - [redacted]
    - [redacted]
    - [redacted]

14. CONTRIBUTING TO THE GLOBAL GRID STUDY

A. *Innovation objective & problem to solve*

Problem & innovation objective

This project stands within the context of the Global Grid [1,2], which is a conceptual vision of what could be the future of electric power systems in a world with 100% renewable energy resources. This vision suggests developing inter-continental electrical connections in order to not only gain access to high-potential remote energy resources (wind and solar) and large storage capacities (pumped-hydro), but also to compensate for the natural daily and seasonal fluctuations of renewable energy sources. The Global Grid approach may also include the possibility of enabling optimised deployment and operation strategies for large-scale generation and storage capacities which are currently unevenly distributed across regions.

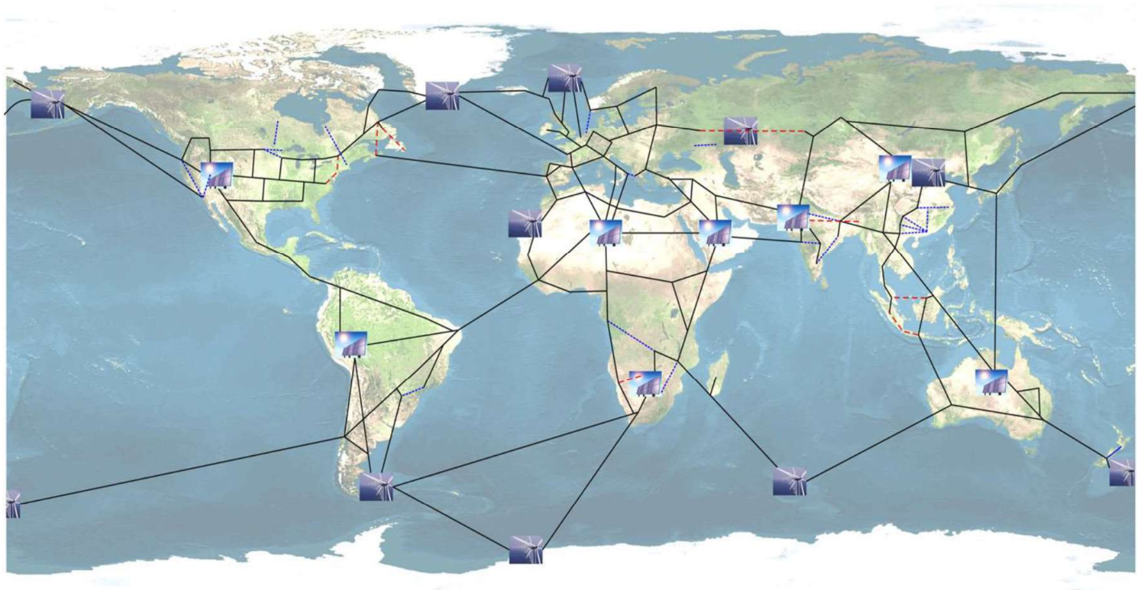


Figure 48 - *A possible Global Grid. Source: S. Chatzivisilieadis, D. Ernst, G. Andersson, "The Global Grid," Renewable Energy, Elsevier, 2013.*

This project first proposes to take a step back from the global grid approach by focusing on the European network and, in particular, Belgium. Based on the current characteristics of the European power system and considering state-of-the-art research on this topic such as the TYNDP scenarios [3], we first propose to study several cases related to electricity connections from Belgium to neighbouring countries and continents.

From the methodologies developed and the results obtained when studying the above-mentioned regional cases, this research project will then investigate the optimal pathway towards worldwide (ultra-) high-voltage interconnections in terms of (i) transmission grid evolution, (ii) renewable energy generation capacity deployment and (iii) storage capacity deployment, in particular considering the specificities of Belgium. A target situation is defined as a set of renewable energy potential sites associated with installed capacities of each renewable generation technology, electricity demand profiles associated with geographic locations, storage capacities and high-voltage transmission corridors to connect adjacent regions. Optimising the transition from the initial to the target situation translates into choosing a planning and investment path which may lead to the desired outcome while optimising a given objective function (e.g., associated with costs, emissions, etc.).

[1] S. Chatzivasileiadis, D. Ernst, G. Andersson, "The Global Grid", Renewable Energy, vol. 57, pp. 372-383, Elsevier, 2013.

[2] S. Chatzivasileiadis, D. Ernst, G. Andersson, "The Global Grids for Harnessing World Renewable Energy" in "Renewable Energy Integration: Practical Management of Variability, Uncertainty and Flexibility in Power Grids", Academic Press, 2014.

[3] TYNDP 2018 Scenario Report Main Report.

B. Project definition and planning

Overall type of the project (innovation phase) and program

Exploration phase

Define a long term system perspective

Separation into work packages

Research approach

Our research approach may be separated into the following steps:

(i) Studying local/regional cases related with the connection between Belgium and renewable energy sources outside mainland Europe (e.g. the Sahara Desert, Greenland, the Middle East);

(ii) From the study of these regional cases, developing a methodology for studying worldwide interconnections, which includes:

  a. defining target situations (generation, transmission, storage, adequacy) at global level;
  b. optimising such investment paths regarding their cost-benefit analysis (CBA) basis.

1.1. First work package: regional case studies

In this first work package, we propose to investigate several regional case studies. Each case study corresponds to a specific task and is divided into two main parts: (i) a resource analysis, and a (ii) a cost-benefit analysis section. The goal of the resource analysis section is to evaluate the levels of both magnitude and complementarity (i.e., level of correlation in time between regions) that may be provided by a given renewable energy resource field with respect to local renewable resources. The goal of the cost-benefit analysis section is to develop a rigorous, hierarchical approach for isolating the different items of capital and operational expenditure, as well as different sources of revenues and avoided costs in the deployment of the European power system, as well as understanding to what extent (part of) these expenditures and revenues may evolve in the coming decades.

1.1.1. Task 1.1 - Case study 1: studying the connection between Belgium, Europe and North Africa

In a first step, this project will investigate the benefits of connecting Belgium and Western Europe with North-Africa. The goal of this first case study is to evaluate to what extent harvesting renewable energy from the North African region is achievable, both from an engineering as well as an economic point of view.

- The resource analysis part of this task will assess the degree of resource complementarity that could be provided by the resource-rich North African region towards Western Europe and Belgium, mainly due to the superior resource availability in the former (e.g., the net superior solar resource in the Saharan Desert is expected to balance common PV shortages in Western Europe. Extreme conditions leading to solar PV efficiency drops (e.g., high temperatures) will also be investigated).
- The cost-benefit analysis part of this task is based on two parts:
    - Evaluating the benefits of connecting North African renewable energy fields to the Continental European grid and, in particular, the benefits that the Belgian grid can obtain from this connection. These benefits may include deferred CAPEX and OPEX expenditures in European investments, conventional production, storage, inland grid reinforcement or development, etc.;
    - Evaluating costs (CAPEX and OPEX) associated with the different aspects of the North African renewable energy development plan, the HVDC connections and the connection with the European grid, and in particular, Belgium.
- Also, this case study will propose to compare the so-called “Desertec” and “Ibertec” approaches. While “Desertec” is the name that was originally given to the project of harvesting solar energy from the Sahara desert, the term “Ibertec” refers to the idea of collecting solar energy from the Iberic Peninsula (Spain and Portugal), and, by extension, from Southern Europe regions.

1.1.2. Task 1.2 - Case study 2: studying the connection between Belgium, Europe, North Africa and Greenland

As a second case study, this project will investigate the benefits of connecting the {Belgium, Europe, North-Africa} interconnected area with the south-east of Greenland, which benefits from the semi-permanent occurrence of katabatic winds (i.e., wind regimes driven by the force of gravity and leading to net superior wind resource compared to European locations). In particular, this case study will investigate how wind energy from Greenland may show complementarity with wind and solar energy from Western Europe and North Africa.

- The resource analysis section of this task – as well as being based on time series of meteorological data – will be dedicated to the study of the degree of complementarity and energy production levels of Greenland with respect to the {Belgium, Europe, North Africa} wind fields. The goal of this second work package is to assess the degree of complementarity that could be provided by potential south-eastern Greenland wind sites. That is, katabatic wind generation in Greenland may compensate for wind-free periods in Western Europe with a sufficiently high probability. Not only the un-correlation in time but also the wind level (production expectation) will be assessed, as well as the extreme conditions (wind, temperature, etc.) on which the wind turbine technology would depend. Also, a specific focus will be made on studying the complementarity of Greenland wind resources with solar energy resources from North Africa.

- The cost-benefit analysis section of this task is based on two parts:
  - Evaluating the benefits of connecting Greenlandic wind fields to the Continental European grid, and in particular, the benefits of the Belgian grid. These benefits may include, as in section 2.1.1., avoiding CAPEX and OPEX expenditures in renewable fields, conventional production, storage, inland grid reinforcement or development, etc.;
  - Evaluating costs (CAPEX and OPEX) associated with the different parts of the installation of the wind turbines, the HVDC connections and the connection with the European grid, and in particular, Belgium. Special attention will be paid to cable technologies, especially for submarine cable routes for connecting Greenland to the European continent.

1.1.3. Task 1.3 - Case study 3: studying the connection between {Belgium, Europe, North-Africa, Greenland} with the Middle East and Asia

The objective of this third step is to evaluate the suitability of connecting the block {Belgium, Europe, North Africa, Greenland} with Middle East and Asia. In addition to the integration of additional energy fields, this third case study will also investigate the potential benefits of increasing the time-zone coverage of the resulting interconnected grid.

- The resource analysis section of this task will be dedicated to the study of the degree of complementarity and production level of {Middle East, Asia} renewable energy resources with respect to {Belgium, Europe, North Africa, Greenland} renewable energy fields based on time series of meteorological data.
- The cost-analysis section of this task is based on two parts:
  - evaluating the benefits of connecting the Middle East and Asia with the Continental European grid, and in particular, with Belgium; these benefits may rely in avoiding CAPEX and OPEX expenditures in renewable fields, conventional production, storage, inland grid reinforcement or development, etc;
  - evaluating costs (CAPEX and OPEX) associated with the different parts of the installation of the solar PV arrays and wind turbines, the HVDC links and the connection with the European grid, and in particular, with Belgium;
  - this subtask will carefully evaluate to which extend the time-zone extension of the resulting grid influences (positively, negatively or neutrally) the cost-benefit analysis.

1.2. Second work package: from regional case studies to Global Grid interconnections

The goal of this second work package is to extract knowledge and assess methodologies developed in the context of the previous regional case studies in order to tackle the worldwide global grid case.

1.2.1. Task 2.1 - Assessing global generation, storage and transmission potential

This task will focus on two aspects related to the quality of worldwide renewable energy generation sites. First, it aims at studying the geographical and meteorological aspects associated with various renewable energy locations (in order to evaluate the theoretical generation/storage potential of these given locations). Second, once the theoretical potential is estimated from meteorological data, it will then be necessary to calculate the amount of energy that can technically be sent (or stored) from these sites to the places of consumption, given a set of technologies. This implies calculating the technical potential in situ, given the technologies used (wind turbines, photovoltaic panels, etc.). This has to take into account the technologies for transporting and/or storing the electricity previously collected. This task will address the following:

- assessing the technical and economic generation/storage potential of renewable energy sources all around the world, based on state-of-the-art generation and transmission technologies;
- assessing global electricity and energy consumption for a set of nodes;
- assessing the feasibility of connecting renewable energy sources and storage capacities with consumers, in particular, taking advantage of connecting both latitudinal hemispheres of the world in order to cover fluctuations associated with the seasonal cycles.

1.2.2. Task 2.2 - Target situations and optimal investment paths

From the potential analysis carried out in the first work package, the second work package will focus on the design of target situations. Each target situation is defined as a snapshot of generation and storage capacities and demand profile assumptions, as well as electric corridors connecting regions of interest. Each target situation may be obtained from, potentially, many different deployment plans regarding generation, storage and transmission capacities.

1.2.3. Task 2.3 - Optimising the path to target situations

A path from an initial to a target situation is defined as a series of deployment steps with their associated costs, benefits, emission reduction potential, as well as the assessment of other externalities. The core of our approach is dedicated to computing optimal sequences of deployments so that the techno-economical trajectories from the initial to the target situation are optimal. Looking for optimality implies defining an objective function allowing for evaluating any association (target situation, path to target), which will also be a sub-objective of this work package.

Planning by work package

This work is envisaged as a two-year project carried out by a post-doctoral researcher in collaboration with Elia and other researchers from the Smart Grids laboratory of the

University of Liège. It is divided into six phases of [redacted] months each according to the following GANTT chart. The overall project will last [redacted] months.

Figure 49 – Global Grid work package planning

C. *Context/stakeholders in the project*

In this study, the only partner is Liège University which is the main driver of the project. On top of the financial contribution, Elia is supporting as an expert but also as a challenger during the steerco.

D. *Implementation plan*

After the study, the results might be re-used as a basis for a very long term study at Elia. Depending on the result, it the outcome is interesting for the grid and more specifically for Elia consumer, we could start reflecting on the role Elia could play in the development of global grid.

15. ASSESSING PREDICTIVE MAINTENANCE TO IMPROVE ASSET MANAGEMENT EFFICIENCY

A. Innovation objective & problem to solve

Problem

According to norm DIN EN 13306, maintenance activities can be distinguished as:

I. Preventive maintenance
   a. Time-based maintenance;
   b. Condition-based maintenance;
   c. Predictive maintenance.

II. Corrective maintenance
   a. Deferred corrective maintenance;
   b. Immediate corrective maintenance.

The predictive maintenance consists in determining the condition of in-service equipment in order to estimate when maintenance should be performed and is generally based on artificial intelligence.

To evaluate the steady-state condition and estimate the life span of an Elia asset (e.g. for a synchronous generator, a power cable or transformer), the following components need to be considered:

- a database for fault detection and troubleshooting;
- a variety of measuring techniques, monitoring devices and sensors with a direct function to collect the necessary data of specific power equipment;
- the application of robust diagnosis software and expert systems that enable the automated interpretation of signals, data and corresponding parameters through, e.g., clustering, machine learning or deep learning methods to identify certain patterns that might cause damage or lead to a failure;
- moreover, the derived information show potential to be implemented in SCADA systems to increase the amount of automation.

Advantages & field of application

In today's Elia grid, the maintenance activities follow a certain schedule for inspections and testing techniques. However the timing is not always optimal: some maintenance could have wait longer resulting in an over cost or should have happened earlier resulting in an unplanned outage. By having a real time concrete image of the overall condition of specific equipment available, a cost-saving benefit by reducing the frequency of inspection intervals can then be expected.

Figure 50 – Transformer example

Example 1: **Power Transformers**

- Extending the lifetime of a transformer by considering data (e.g. upper coil temperature and key gases such as nitrogen and carbon dioxide) to avoid accelerated aging.
- Being aware of data and derived information of important Transformers for operational purposes (evidence of excessive moisture or degradation of dielectric integrity of the overall insulation).

Example 2: **Power Cables**

- Avoiding local damage at cable joints measuring Partial Discharges or online fault detection within Sea Cables.

When it comes to substations and switchgear assemblies, monitoring devices and diagnosis techniques are currently not applied on a regular basis. One reason for this is the layout of switchyards. In transmission grids, those assets are designed with multiple busbar arrangements and couplings as well as sectionalisation to provide a variety of switching options. When a failure may occur, those assets remain in operation but only with partial de-energisation (redundancy). Although, devices for gas-insulated switchgear exist, e.g. for SF6-Leakage or Circuit Breaker auxiliary engines, which can be implemented in a predictive maintenance approach.

The predictive maintenance approach aims at a permanent evaluation of the condition of an electrical equipment using data collected by various installed sensors and then analysed to identify maintenance/replacement needs.

All derived data and information are used to train model and based on historical data run prediction algorithm to make smarter investment decisions (maintenance, replacement). Therefore, it is necessary to create a database containing asset defects and maintenance operations, as well as a variety of measurement techniques, monitoring devices and sensors with a direct data collection function. In addition, robust and sophisticated diagnostic software will have to be developed to allow automated interpretation of the corresponding signals, data and parameters.

Objective

In Elia's particular case, the objective of predictive maintenance will be, first, to predict when equipment failure could occur and, second, to prevent the occurrence of failure by performing maintenance. Monitoring future failures allows maintenance to be planned before a failure occurs. Ideally, predictive maintenance makes it possible to reduce maintenance frequency as much as possible in order to avoid unexpected reactive maintenance, without incurring the costs associated with excessive preventive maintenance.

Key questions:

- Which assets are needed?
- Which data sources and interfaces are necessary?
- How can we gather Kknow-how as soon as possible in order to translate the approach into added value for the Elia Group?
- Who could be potential partners for the POC?

Elia plans to test the impact of predictive maintenance on different network elements (transformers, etc.). The first step will be to evaluate on which assets predictive maintenance can have an impact. Once the assets have been identified, Elia will capture the data to be processed and analysed using a predictive maintenance algorithm.

The current research activities focus on adapting the available monitoring devices and sensors for Power System Operation and Asset Management purposes. Yet there are only a few research projects dealing with the autonomous interpretation of generated data due to clustering, artificial neuronal networks or deep learning methods.

Impact for Elia: KPIs and/or hypothesis (qualitative and quantitative)

In comparison to a classic maintenance approach predictive maintenance shows more transparent the necessity of maintenance activities. The target is to increase the efficiency on maintenance activities by maximizing the impact of maintenance work (better focus on critical asset close to failure) and therefore reduce unplanned outage risk.

Use of the results

As explained, the expected result will be used to optimise and thus reduce the number of maintenance occurrences to the level actually required. It will also prevent unexpected failures and reduce the risk of unplanned network outages that could lead to critical situations.

It can be expected that an increase in the share of automation will lead to an optimisation of the operation of the network infrastructure. However, these claims must be verified by Elia. In addition, new concepts based on big data can be introduced to promote renewable energies in a sophisticated market design.
The use of the results will be mainly seen in improvements in the following fields:

- **efficiency of maintenance activities;**
- **reduction in the environmental impact.**

B. *Project definition and planning*

Overall type of the project (innovation phase)

Exploration innovation

Using analytics to optimize the grid development and O&M to enable better flexibility and efficiency

Separation into work packages

The project will be conducted in order to assess the feasibility for Elia regarding AI-supported monitoring of the maintenance activities.

The following work packages are planned.

- WP 1 Definition of data standards, database structure;
- WP 2 Development of AI algorithm;
- WP 3 Identification of data sources and check data quality;
- WP 4 Completion of database and structuring of data;
- WP 5 Training of AI algorithm with a training data set;
- WP 6 Testing of AI algorithm with a test data set;
- WP 7 Comparison of results with benchmark and interpretation of data.

Planning by work package

The project will be planned in [redacted] and conducted in [redacted]

C. Context/stakeholders in the project

The project in the context of the strategic objective is entitled *"Become a digital utility (assets are monitored and inspections are automated)".* Major stakeholders are:

- ENTSO-E as a supporter of new technology/process development;
- TSOs with similar requirements regarding digital transformation;
- service providers, suppliers and start-ups;
- universities and scientific institutions.

It is planned to cooperate with an independent partner in order to keep the data sovereignty about the data generated during the project duration. Therefore the sub-project will be conducted with a scientific institution. The choice of the partner is not finalised yet (potential one would be Sparkbeyond).

Providers of predictive maintenance algorithms will be selected to perform the tests, specialised in prediction algorithms (based on AI), especially for maintenance.
The aim is also to learn from other TSOs in advance to assess the usefulness of this new technology for the maintenance of Elia's infrastructure.

D. Value development plan

How the project contributes to the strategic objectives

The underlying strategic objective is *"Become a digital utility (assets are monitored and inspections are automated)".*

Data and automation have a substantial impact on the world of tomorrow. To understand the prospects arising from the digital opportunities, we need to embrace these. This requires a deep understanding, achieved by testing the opportunities and prototyping the most promising technologies. This innovation project fulfils the strategic objective.

Link with Elia's other innovation objectives

Further strategic objective:

State-of-the-art (transmission) assets with the least possible impact on society

The development of processes gives us opportunities to improve our day-to-day work and the ecological footprint of suppliers and service providers but also improve the security of supply by decreasing the outage risk. We need to step up information flows and knowledge exchange within the Group to focus on the relevant topics and to work efficiently. Additionally, the communication with partners and stakeholders gives us a better understanding of how we can have a minimal impact on the environment at minimal cost while maximising reliability.

Implementation plan

The implementation plan of the innovation project consists of the following items:

- finalisation of the activities described;
- compilation of a sandbox to test the predictive maintenance approach on two or three use cases;
- adjustment of working processes.

Potential next steps

- Choice of an independent partner to define the data quality and standards

16. IDENTIFYING AND TESTING VALUE-ADDED SENSORS FOR ASSET MANAGEMENT AND SYSTEM OPERATIONS

A. Innovation objectives & problems to solve

Problem

High demands are placed on sustainable power grids, which forms the heart of the new energy infrastructure to secure energy supply in the future as well as to be able to react effectively to fluctuating power generation from wind and solar energy. In addition to optimum system control through intelligent measuring systems and efficient load management, careful monitoring of the operating resources of high-voltage and medium-voltage systems is essential. To achieve this new IOT sensors are available (acoustic, magnetic field…). Sensors can then be a standalone applications (monitoring) but also a key enabler for other applications requesting new data collections (e.g. predictive maintenance).

This integration brings the sensor directly into the area in which faults or damage occur and cannot be detected "from the outside" or only very late. The sensory elements integrated in the respective high-voltage equipment and systems without feedback, are connected to an intelligent data management system. In this way, it is possible to combine, analyse, evaluate and visualise all the necessary information, signals and data in a practice-oriented manner. This measurement system is also forward compatible for the acquisition of further measurement information from sensor technology of other physical principles.

In order to capture the know-how and the capabilities, Elia started a program to understand, identify and test relevant sensors. For example, the following sensor technologies are focused on:

- acoustic sensors (example presented in figure 51);
- EMF sensors (example of wristlet embedded sensor);
- sensors in substations to automate processes.

Figure 51 - Acoustic sensors tested for Nemo substation

Figure 52 – Electro-Magnetic Field sensor on a wristlet

Objective

Several sensor solutions for network assets are already available on the market or under development. In order to understand the benefit of these solutions, we will proceed with specific proof of concepts. After an internal analysis, initially, interesting use cases which are expected to yield a substantial benefit will be conducted. Additionally, specific workshops will be planned to identify further solutions.

The goal of this program is to find the sensors that generate the most interesting data for the development of new algorithms and/or for monitoring the condition of network assets. The following technologies will be tested in particular:

- acoustic sensors;

- EMF sensors for safety measures and protection of technicians and field engineers.

The value assigned to the implementation of these new sensors in maintenance activities must be assessed and verified.

Furthermore, Elia will participate in a European project led by Fingrid. The objective is to identify interesting sensor applications for Elia.

This listing of sensors will then lead to a selection of high value-added sensors that will be tested in order to provide:

- either standalone applications (like the case of the acoustic sensors);
- or additional input for other algorithm (e.g. for predictive maintenance).

Impact for Elia: KPIs and/or hypothesis (qualitative and quantitative)

As for example for predictive maintenance the usage of sensors shows more transparent the necessity of maintenance activities. **The target is to increase the efficiency on maintenance activities**.

One important additional aspect is the environmental impact. Due to the reduction of activities of supplier and service provider it is expected that by applying the predictive maintenance approach emissions will be reduced.

Use of the results

It can be expected that an increase in the share of automation will lead to an optimisation of the operation of the network infrastructure. However, these claims must be verified by Elia. In addition, new concepts based on big data can be introduced to promote renewable energies in a sophisticated market design.

The use of the results will be mainly seen in improvements of the following fields:

- ✓ **efficiency of maintenance activities (quantification to be evaluated);**
- ✓ **reduction in the environmental impact**

B. *Programme definition and planning*

Overall type of the programme (innovation phase)

Exploration innovation

Develop the asset of the future and use connected devices to maximize safety, efficiency and insights

Separation into sub-projects

SP 1 Proof of concept by testing an acoustic sensor application ([redacted]

SP 2 Proof of concept by testing an EMF sensor application ([redacted]

SP 3 Participation in an ENTSO-E sensor project (6th sense)

SP 4 Assessment of the impact of additional identified high value-added sensors

Planning by sub-project

The SP1-3 sub-projects will be planned in [redacted] and conducted in [redacted], while SP4 will start in [redacted] and be finalised in [redacted].

C. Context/stakeholders in the programme

The activities are performed in the context of the strategic objective *"Become a digital utility (assets are monitored and inspections are automated)".* Major stakeholders are:

- ENTSO-E as a supporter of new technology/process development;
- TSOs with similar requirements regarding digital transformation;
- service providers, suppliers and start-ups;
- universities and scientific institutions.

The initiatives will be carried out in partnership with specialised sensor manufacturers, such as [redacted] and [redacted] (SP 1 and 2).

For SP 3, Elia will work in collaboration with other TSOs, especially with Fingrid which is leading the initiative.

For SP 4, Elia will select partners depending on the identified high added value technology.

D. Value development plan

How the programme contributes to the strategic objectives

The underlying strategic objective is *"Become a digital utility (assets are monitored and inspections are automated)".*

Data and automation have a substantial impact on the world of tomorrow. To understand the prospects arising from the digital opportunities, we need to embrace these. This requires a deep understanding, achieved by testing the opportunities and prototyping the most promising technologies. This innovation program fulfils the strategic objective.

Link with Elia's other innovation objectives

Further strategic objective:

State-of-the-art (transmission) assets with the least possible impact on society

The application of sensor technologies gives us opportunities to improve our day-to-day work and the ecological footprint of Elia as well as of suppliers and service providers. We need to step up information flows and knowledge exchange within the Group to focus on the relevant topics and to work efficiently. Additionally, the communication with partners and stakeholders gives us a better understanding of how we can have a minimal impact on the environment at minimal cost while maximising reliability.

Implementation plan

The implementation plan of the innovation activities consists of the following items:

- finalisation of the testand evaluation of results;

- Definition of the integration roadmap.

Potential next steps

- Implement both proof of concepts.
- Conduct an internal analysis to define further relevant sensor technologies to be tested within Elia.
- Roll out the identified sensors to Elia's entire grid.

17. INTEGRATING DECENTRALIZED ASSETS IN THE FLEXIBILITY MARKET

A. Innovation objective & problem to solve

Problem definition

The integration of decentralized flexibility assets, such as heat pumps or electric vehicles (EV) into the energy system is one of the main challenges system operators will face in the future. If the number of EVs in the fleet increases, which is in line with predictions and with the government ambition, these cars can cause problems on the network. Similarly, the rise of heat pumps could also result in a load increase in critical conditions of a very cold day.

On the other hand, it is clear that all these new, decentralized assets can represent a considerable new amount of flexibility. By actively steering the moments at which the decentralized assets are allowed to consume electricity and when not, the assets can be leveraged as a balancing product, or any other flexibility product for the grid. This means that, for instance, cars can start charging faster when the grid frequency rises (i.e. too much production or not enough consumption on the grid) and charge slower or stop charging when the overall consumption surpasses production. Going one step further, in case the car would be connected to a [redacted] charge pole, the energy that is stored in the battery can even be injected into the grid.

Next to this, in a future where dynamic grid and electricity tariffs are anticipated, it could become interesting for consumers to charge their car during the day at work, or using power produced by their PV panels, then use this power during the evening peak to cook (when the electricity would be more expensive), and subsequently recharge their car during the night when the electricity is cheaper again. Additionally, people can heat their house with their heat pump (and accumulator) during moments there is a lot of wind, this way helping the system operator to operate the grid.

It is, however, unclear how these assets need to be managed properly in order to arrive at a safe and technically feasible imbalance market. It is necessary to learn what the technical capabilities of the assets are, for instance in terms of reaction speed or dynamics, and how the interface with the low voltage grid operators can be made. These are learnings we hope to receive from this project.

Objective

The general objective of the project is to develop interfaces, best practices and business processes within Elia and the DSO's that are needed to unlock the power of decentralized assets for using them as balancing products, on the short term, which means within the framework of the current state of technology and market products.

This project has been broken up into multiple parts. The first part (in short referred to as V2G project) focusses at integrating EVs, connected either with unidirectional and bidirectional charge poles, into the FCR product. The overall scope can be reframed as "Feasibility and market study concerning the controllable charging behavior & potential of EV drivers in order to analyze the integration of EV in the FCR via controllable charging stations."

The main objective of the [redacted] project is to assess whether an aggregated pool of [redacted] charging poles can provide FCR services to the high voltage grid. In addition, we would like to assess whether the bi-directional charging station can be used to create value for the end user by providing local energy services.

This requires a better understanding of the vehicle and charge pole technology, and the influence of the driver's behavior on the availability of the services provided. The value [redacted] must be known, and the appropriate aggregation method developed in order to arrive at a service that is reliable and will not push the grid away from its safety limits.

The experience gained in the project will be shared with the market development department and with the working group responsible for flexibility of Synergrid, in order to gain insight in the possibility of kW scale assets to participate in the ancillary service (AS) market (which is a key objective of Elia: putting the consumer at the center). If it is found that this is not feasible with the current market design, the design might need to be adapted in order to reach technology agnostic products. The learnings for the FCR product can be transferred to the market development department, in order to be extrapolated towards similar products (aFRR, mFRR) we procure.

For the second phase of the project, we want to work more closely together with at least one DSO, or within the framework of the Synergrid Flexibility working group. This way, we can investigate how decentralized flexibility assets, for instance heat pumps, can be clustered and aggregated in order to provide either local or global congestion management.

Based on the experience gained in the second project, we do not exclude the possibility to define follow-up projects in the future.

Impact for Elia: KPIs and/or hypothesis (qualitative and quantitative)

One of Elia's goals is to move towards a consumer centric system. However, traditionally AS have always been delivered by CIPU units, which makes that most experience we have comes from AS delivered by large generators which are guaranteed controllable. Big effort has been made in the past and still today, to arrive at technology agnostic product description for most of the AS, but not all decentralized assets that can offer flexibility have already been put to the test. This means that EVs and heat pumps, along with other upcoming decentralized assets, are products that in theory should be able to participate in a consumer centric market, but have a different behavior than the known flexibility providing assets. For instance, since one heat pump is too small to have effect on the high voltage grid, multiple units shall be aggregated in order to be useable as FCR asset. Next to this, correct prediction of charging patterns of EVs with their associated flexibility and customer constraints, and risk mitigation of unavailability should be explored in detail, tested, and understood by Elia.

Validation of the services is another topic that is to be explored, since it is unlikely that receiving information of small assets on a single unit level is the way to go. Therefore, it is important that Elia gets a clear view on practical issues that can arise when processing this amount of data on asset level.

Through the project, Elia aims to gain a better understanding of the practical obstacles to the integration of kW scale assets into the AS market and the correct activation needed for delivery of existing market products, in order to facilitate the integration of new technologies in the balancing of the market. Theoretically, the more assets that can take part in the AS market, the more volatile the market will become, thus the lower the price for the end user should be. The first tests will be done by means of EVs.

Last but not least, the more insight we gain in the aggregated market, the better we would be at avoiding gaming or other unwanted behavior that could have a negative impact on the stability of the grid.

To achieve this goal the different steps are:

- Evaluate functioning and potential [redacted] in the upcoming Belgian FCR market structure;
- Better understand the big challenges related to data-management, data-processing;
- Better comprehension of market design, actors and settlements for the integration of new technologies in the FCR market;
- Propose recommendations on market products, market design and settlement based on observations;
- Simulate and evaluate the optimal power availability [redacted] to deliver AS at different delivery periods.

In the second part of the project, we will dive deeper into processes and interfaces that have to be made with DSOs before we can activate the available flexibility. The focus of the second project will be less strong on currently existing AS (such as FCR in the first part of the project), but the scope is to design an interface and best practice with the DSOs, in order to create a market in which both transmission and distribution system operators will have access to and control over a large number of flexible assets.

Use of the results

Supporting the energy transition						
Improving public acceptance						
Boosting Elia's efficiency levels						
Enhancing market design						

The results of the project will enable Elia to better quantify the potential of distributed assets for the provision of AS. For the first project, the potential will clearly be linked to the driver's habits, but this will not necessarily always be the case. However, with other types of distributed assets, other challenges will arise.

The projects will also provide an understanding of the technical constraints associated with the implementation and operation of distributed assets for network services, for instance with regards to data collection. Elia will then be able to take into account the constraints and functionalities in the design of a technology-agnostic AS market.

Proposals for adaptations to the regulatory framework may also be introduced, if this seems necessary.

Ultimately, Elia will be able to unlock the potential of the upcoming wave of distributed as new and upcoming flexibility source, before these assets will overwhelm us with problems due to unmitigated, natural behaviour. This way, the opportunities that are arising can be grasped, before they threaten the adequacy, stability or safe exploitation of the high voltage grid.

B. Project definition and planning

Overall type of the project (innovation phase)

Exploration innovation

Understand and enable the integration of new, decentralized, assets in the market

Separation into work packages

The project is currently split into two parts, and it is likely that a third part will follow, depending on the results of the first parts.

In the first part, Elia together with a charge point operator, aggregator and software provider, aims at simulating the integration of a number of EVs in the FCR market. To this end, the charge power of a small number of vehicles is controlled to follow the grid frequency. Additionally, prequalification, power test and energy test are executed, on a small scale (kW scale, 10s of vehicles), so the market is not disturbed and conclusions will be extrapolated.

The second part of the project will include low voltage grid operators in the process. All the learnings in terms of data handling and activation control from the first part of the project will lead to new insights and problems to be solved in a second phase. However, many of these problems cannot be solved by the TSO alone, since it can concern for instance local congestions in case the TSO activates many assets in the same region. Therefore, the learnings will be transferred to the responsible of these networks to investigate how they can be solved. .

Planning per work package

The first part of the project, with its learnings, is to be finished early [redacted] After this, the analysis and problem definition of the outcome will start, along with discussions with the DSO, as explained a crucial partner in this type of projects. The next project can then be launched to tackle the issue of TSO-DSO interfacing. Subsequently, other projects can be launched to analyze the impact of other applications, such as radically new products (e.g. load shifting or virtual inertia).

C. Context/stakeholders in the project

The current project is performed together with three stakeholders: NewMotion, Enervalis and EVConsult.

- EVConsult is an independent consultancy firm that has been active in the electrical mobility sector since 2007 and is the market leader in the Netherlands. EVConsult provides consultancy services ranging from high level EV implementation strategies to EV project management. EVConsult takes the role of project manager in the project;
- Enervalis NV develops high-tech software that enables energy producers, distributors and consumers to save money by automatically optimizing their energy supply, storage and flexibility. Enervalis provides the required information systems for the project, develops the aggregation software for management of chargers in the project, and implements the necessary interfacing to be able to provide an FCR service;
- NewMotion is a supplier of charging poles and Charge Point Operator with the ability to provide and manage the necessary specialty hardware, namely charging stations [redacted] technology. NewMotion manages the largest charging infrastructure network in Europe and the third largest worldwide.

For the future projects, a relevant stakeholder (Synergrid, Fluvius, Sibelga …) is yet to be selected and approached. .

D. Value development plan

How the project contributes to the strategic objectives

If the inclusion of distributed assets increases the availability and liquidity of ancillary services on the market, this will benefit not only the security, reliability and efficiency of the grid, but also the affordability for the society. Subsequently, by identifying gaps in the current market design, we can make sure that the market evolves towards a future minded setup. Because of this, the interface between TSO and DSOs is going to become more important in the future, as well as the proper management of multiple distributed assets. Therefore, we need to learn how to incorporate this into our business, and plan the way forward together with relevant stakeholders.

Implementation plan

Based on the findings of the first part of the project, Elia expects to have a better insight in the potential of EVs for delivering ancillary services, and the match between the delivery of these services and the technical limits of the car/charger combination. This experience will help to assess whether (i) in the current market design, EVs are able to be used as a source of flexibility, and (ii) whether the potential is high enough for pushing the market design further.

On top of this, when developing or testing a new market design, Elia will have insight in the methods of aggregating small assets, which means we will be able to avoid gaming, and efficiently gather data for a correct settlement after service delivery.

The issues that will arise in a future where the TSO could control assets on the DSO grid will be tackled by properly studying them during a joint project.

Potential next steps

The potential next steps can be split into two parts. The first action has been explained above, this is challenging current market products, market design and settlement, based on the experience that is gained with the project. This way, an AS market that is open for all assets, also small and distributed, will be reached, benefitting the end user.

Secondly, the insights gained will help to assess whether distributed assets such as cars are able to help us in solving future problems. One of these problems might be voltage regulation, or the lack of inertia in the grid. Alternatively, in cooperation with DSOs we can start thinking about e.g. congestion management with EVs or other assets, which fits well within the framework of our IO.Energy program.

- This way, we will arrive at a future proof energy world. It is clear that it will be impossible in the future to rely on big centralized plants to feed and balance the grid, therefore these projects are necessary for our position towards this.

18. SUPPORTING DECISION-MAKING [redacted] [redacted] [redacted] OF DISPATCHER WORK

A. Innovation objective & problem to solve

Problem

The work of our dispatchers becomes every day more complex; due to the increase of distributed energy resources, the increasing international fluxes which can give rise to sudden changes in direction of the flow or new types of assets such as HVDC that are introduced into the system. On top of that, the job of a dispatcher can be described as often being exposed to a peak of activities, to face the unforeseen, to think about everything, all while taking into account that is projected on ten different screens.

The decisions that are made by the dispatcher are always collaborative, which means that many counterparts and interdependencies need to be considered. The dispatcher needs to know all the grid constraints, especially since the grid is operated closer to the limit than before. He needs to cope with many uncertainties, in the sense that predictions might differ from reality, weather conditions can suddenly change, the market can deviate, etc. Today, the dispatcher needs to work with a multitude of tools, all used for managing another part of the grid.

With all this information in mind, Elia is looking at creating a smart dispatching, which can first support the grid operator in his daily decision and operation process then ultimately automated maximum of these processes. The smart dispatching can have multiple forms, firstly by automating high effort tasks, and secondly by supporting the dispatcher in his decision process. The smart dispatching will need to be supported by an improved means of forecasting, because one can only trust automatically applied decisions if these decisions are made based on the most accurate and reliable forecasts.

Objective

We aim to further integrate [redacted] artificial intelligence, more specifically machine learning, into the system's management tools. The aim is to provide useful information to the dispatcher so that they can make decisions more quickly, taking into account all available information on the current and future status of the network. This objective is currently divided into three sub-tasks. As mentioned here above, the ultimate vision is to arrive at an auto-pilot for the dispatcher, which means that the three currently defined tasks are just the first step in a long venture that Elia wants to dive into.

Firstly, we are working on a part in which system imbalances will be predicted. After defining the proper input parameters for a machine learning based model, the model is trained and analysed. If the model is able to predict the system imbalance properly (in terms of direction and size), this will lead to a more efficient dispatching and less activation of reserves.

The second part of the project aims at the development of a tool to automate the creation of switching notes. Currently, switching notes are created and checked manually, but due to last-minute changes in the planning up to 60% of the created notes need to be revised at least once. This is a high effort work for the dispatchers that can lead to frustrations. If switching notes can be created automatically, the dispatcher will be able to spend the freed time on other, high return work. We want the tool to create the 'standard' situation notes automatically (e.g. 80% of all notes), only exceptional situations will probably still be handled by a human.

Thirdly, following an incident, the dispatcher needs to act quickly and restore the grid by solving the problems that have occurred. However, in case of incidents, the SCADA system retrieves a large amount of information. In most cases, most of this information is not relevant to the operator. Worse still, some of them have no real meaning because of their aggregation at the field level. This makes it very difficult for the operator to assess and react to the situation, resulting in a risk of a late reaction. Several developments are planned within the framework of this project:

- Development of an intelligent alarm filtering system to display only those alarms that concern the operator, highlighting the root cause of the incident.
- Automatic proposal of corrective measures to be applied to the operator, which summarises the advantages and disadvantages of each of them.
- Automatic application of corrective measures.

As a bottom layer for future projects, we want to look into the creation of a performant digital twin model for the high voltage grid. This digital twin will be used as a layer on which future predictions can be based, and can serve as an input for other use cases, such as a remedial action optimiser.

Impact for Elia: KPIs and/or hypothesis (qualitative and quantitative)

1. For the first part (prediction of system imbalance), we will assess the quality of the model. It is easy to compare the current approach with the results of the new model, and estimate whether the new model gives us a better prediction of the system imbalance. Subsequently, we will assess (qualitatively) the feedback of the end users, thus the dispatchers. We will ask them whether they trust the tool, whether they see it as an added value, and we will also compare the predictions the tool made in real time with the decisions the dispatcher took.
2. The second part, in which we focus on the automation of creation of switching notes (mandatory notes describing the steps for effectively operate an outage), we will assess the quality of the switching notes that were created. Currently, dispatchers have a known ratio of 'first time right', i.e. the number of notes that were correctly created the first time. We want to assess whether an automatic tool can reach a better ratio, the goal being 100% in order to improve the safety of the dispatchers. On top of this, we will qualitatively asses the resistance of dispatchers to change, by automating a part of their work. This will give us insight in how open dispatchers are towards change and the integration of new technologies into their workspace. We will assess the data that is available, both grid data, planning, and notes that were created in the past, to see whether the data is available in sufficient quality to automate the process. Ultimately, the most interesting KPI will be how much time the dispatching can save while delivering the same (or better) quality of switching notes.

3. For the third part, we want to test whether it is possible to handle incidents automatically. The hypotheses for this are that operations will be more systematic, which will avoid confusion in case one person has another way of approaching a problem than another person. The incident processing time shall go down, which will have an effect on the average interruption time after incident, and on the loss of load after incident. The grid exploitation shall become safer, because switching will be less prone to human error.
4. The digital twin concept has yet to prove its suitableness for a TSO, but is a promising technology that might become indispensable in the future. Therefore, Elia wants to test the technology, in order to be ready to apply it when it becomes mature.

Use of the results

Supporting the energy transition						
Improving public acceptance						
Boosting Elia's efficiency levels						
Enhancing market design						

Given the increasing complexity of the transport network, we observe a situation in which the dispatcher will be confronted with an increasingly demanding decision-making process. It will therefore become essential to support the dispatcher in this process to ensure sufficient reactivity for good grid management. This will ensure security of supply and relieve the dispatcher of high effort or low-value tasks.
The projects discussed, namely the forecasting of system imbalances, automatic operating notes and incident management, concern three tasks for dispatchers for which we have determined that machine learning tools could help us to automate them. This will allow us to test this new working method and, once validated, deploy it for larger or more complicated distribution tasks.
Gaining experience by testing the digital twin concept, on the other hand, does not directly apply to a task of the dispatcher that can be automated, but on the other hand will be used as an underlying layer, or a backbone, crucial for future, far-reaching dispatching automation.

B. *Project definition and planning*

Overall type of the project (innovation phase) and program

Exploration phase.

Prepare for the system operations in the new context (HVDC High RES penetration…)

The project is considered as radical innovation, as reaching an auto-pilot for the dispatching is a long term vision, and not something that can be reached easily. Therefore, innovation is clearly in the lead for the projects, closely supported by the system operation departments.

Separation into work packages

The project is currently split into three projects and a fourth explorative analysis. The concrete projects are system imbalance forecasting, automatic creation of switching notes, and smart incident management. In addition to this, we want also to explore the possibilities and advantages of Digital Twin.

Planning by work package

a. System imbalance forecasting

The aim is to introduce into distribution a machine-learning tool that will help grid operators predict and anticipate any expected system imbalances. To this end, we are formulating a machine learning-based model. This model will predict a system imbalance 15, 30 and 45 minutes in advance and inform the dispatcher when action needs to be taken.

The first phase of the project consists of developing the model by selecting the data needed to predict imbalance. Subsequently, the model will need to be implemented into the dispatching, thus an industrialisation phase of the software will be necessary. After implementation into the dispatching, the software will be tested by the dispatcher, and in parallel the results will be compared with actual data, in order to assess the accuracy and usability of the model.

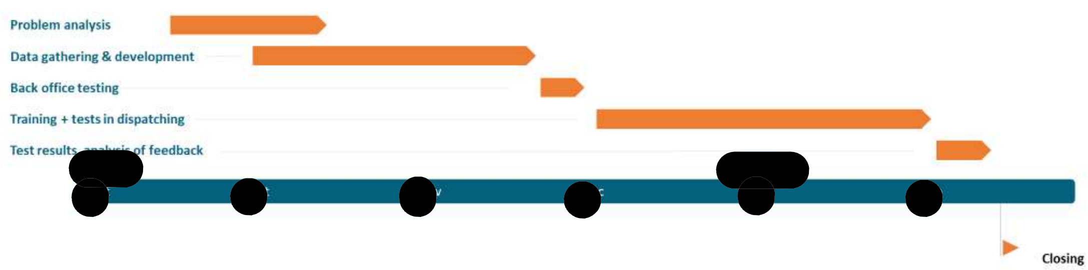


Figure 53 – Planning for WP 1 on imbalance forecasting

b. Automation of operational notes

Drawing up operational notes is an activity for daytime operators. The activity involves bringing together all the steps the field technician and dispatcher must follow to take part of the grid out of service and allow staff to work safely. As the grid topology is liable to change over time, the operational notes should be written as close as possible to the time when the maintenance is performed. This is all the more crucial given the increase in renewable generation, which inevitably entails changes to topology at increasingly short notice. However, this is not always the case because the current process is manual and cumbersome.

The main aim of the operational-notes project is to develop a tool that can evaluate the grid topology and automatically suggest a procedure as close to real time as possible. This means that the most recent typology can be taken into account at all times. In addition, the tool is able to track the (physical) switching process and trigger an alarm when a step is ignored. [redacted]

The project is split into two big phases, in which the first phase will tests some basic KPIs by creating a first, simple model and a minimum viable product

1. Will the tool be able to reduce the workload for the dispatchers, or are many interactions still needed?
2. The creation of switching notes is not a highly unpredictable process that cannot be automated with state of the art skills
3. Is the data related to daily operations and grid topology easily available and of sufficient quality? Will the current tool still be sufficient?
4. Are the right resources available at RCC to operate the tool? – will it be used to its full potential once implemented?

As soon as the first phase is over, a Go/No Go decision will be taken to launch the second phase (planned for [redacted] Then, more qualitative and quantitative KPIs will be tested after a more thorough design and development phase.

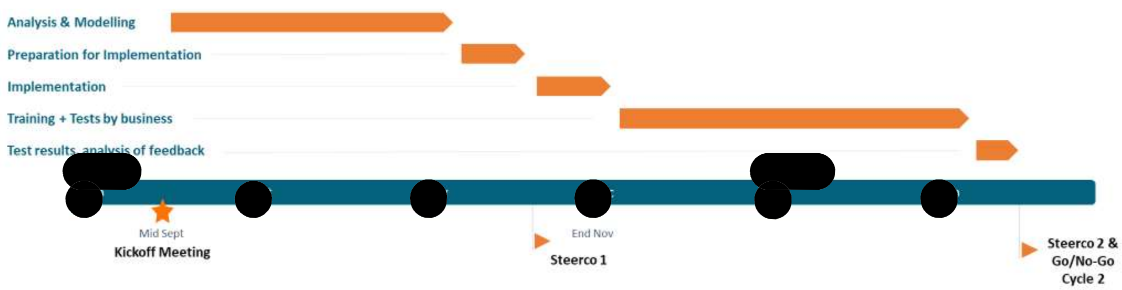


Figure 54 – Planning for WP 2 on operational note automation

c. Incident management

When an incident occurs on the grid or in a substation, the SCADA system retrieves a large amount of information. In most cases, most of this information is not relevant to the operator. Worse still, some of the information has no real meaning because of its aggregation at the field level. This makes it very difficult for the operator to assess and react to the situation, resulting in a risk of a late reaction. Several developments are planned within the framework of this project:

- development of a smart alarm filtering system to display only those alarms that concern the operator, highlighting the root cause of the incident;
- automatic proposal of corrective measures to be applied to the operator, which summarises the advantages and disadvantages of each of them;
- automatic application of corrective measures.

The project will be split up into two phases, of which the first phase will launch by [redacted] and run for six months. This phase will aim at finding out what exists at other TSOs and interviewing them (e.g. RTE with the Apogee project), and test some basic scenarios. After Phase 1, the decision will be made to go towards Phase 2, in which the solution will be more elaborated. This way, we aim at reaching an agile process, which will not eat too many resources in case we discover at the end of Phase 1 that the current state of technology, or skills of the end users, or ways of working in the dispatching, are not yet ready for this kind of automation.

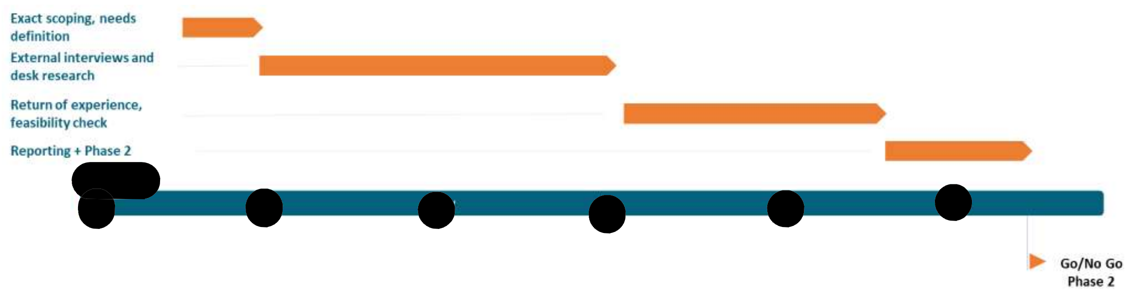


Figure 55 - Planning for WP 3 on incident management

d. Digital Twin

In order to discover the benefit a Digital Twin can bring for the system operations of Elia, we plan a small proof of concept with a start-up. This way, with a minimum effort and budget, we can get an overview of the technology.

The search for start-ups is beginning in September 2019. By November 2019, one start-up will be selected and a POC will be defined together with them. This POC, depending on the scope, is to run for some months. After this, key insights will be shared with key stakeholders, KPIs will be validated and we will know whether a digital twin is worth a venture for the company.

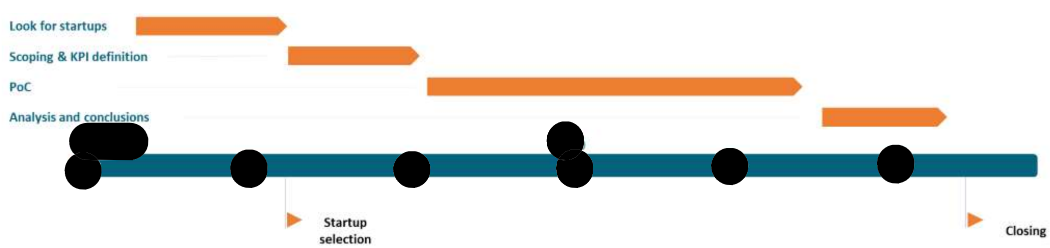


Figure 56 - Planning for WP 4 on the Digital Twin

C. *Context/stakeholders in the project*

As partner of the Artificial Intelligence Laboratory of Elia, [redacted] will support the development of applications for Elia. For some applications, dedicated solution providers will also take part in the projects (start-ups such as Cosmo and Tangent Works). Projects where it is relevant will always have a first phase in which the state of the art is assessed, to be sure we do not reinvent the wheel, and partner up when it is opportune.

With some suppliers of machine learning based models, for instance Tangent Works, the Elia Group is building a sustainable relationship. Therefore, we can trust on a streamlined process in which the start-up will be willing to support Elia where needed and we will achieve the best result by using their solutions.

A similar relationship is built with [redacted] which gives this provider of data science related skills a good insight into the world and problems of Elia. This way, the solutions they can build and propose will be nicely tailored to the expectations of the business.
Elia's innovation team maintains an ongoing dialogue with other TSOs (such as RTE) to learn from their research and shift the focus towards further tests or particular use cases. We have had one exchange with RTE in the past, in which they explained to us their view of the automated dispatcher (Apogee project). That way we will be able to gather their experience and build on it, always keeping in mind the fact that Elia has different kind of problems than RTE (for instance, we handle lower voltage grids, thus we cope with incidents and switching on the grid more often, which means that in parts 2 and 3 of the project exchange of information is limited).

D. Value development plan

How the project contributes to the strategic objectives

The project links to many of the strategic objectives. We want to support the energy transition, and linked to this transition comes a more complex system operation. Therefore, if we can give tools to the dispatcher that will support him in this task, the way towards the energy transition will be easier.
We will also be able to ensure a secure, reliable and efficient grid, that is operated in the best way possible. By taking away high effort tasks of the dispatchers, they will be able to focus on other tasks that will give growth opportunities to Elia.

Implementation plan

Every part has a different implementation plan due to the different nature of the projects.
For the first part, if we see a good performance of the system imbalance model, the first step is to industrialise the tool and put it into the dispatching. This way, the system operator will always be able to anticipate on the imbalances that he can expect.
The second part will be industrialised in case the KPIs and hypotheses are validated. This means that if the solution works, it will be handed over to the business and the switching notes will be automatically created from then onwards. The process of checking the notes will probably need to be reviewed, a project where the business will clearly be in the lead.
For the third part, the implementation into business will be slower, since we envision a tool that will need to work in real time. However, the tool will be able to work in parallel with the dispatcher, which has two benefits: Firstly it can propose to the dispatcher what it would have done, and the dispatcher can take this information and go through an easier decision making process. Secondly, the decisions of the tool can be saved, and ex post the decisions can be compared with decisions the dispatcher took, and analysed in terms of effectiveness.

Potential next steps

The ultimate goal is to reach an auto pilot for dispatching. Therefore, the next steps are clearly there.

For the first part, if the model works well, it can be considered to create a tool that automatically decides when to activate reserves, and to select the cheapest bids, so the system balancing will become a fully automated process.

Secondly, as soon as the creation of the switching notes is automated, we can go one step back and one step further;

- backwards means that the tool will be linked to the planning, so as soon as the planning of outages in the grid changes, the tool can interpret the planning, decide which operation is needed (e.g. connect to earth, or open line etc.) and creates new switching notes that are up to date;
- the step forward means that no human will be in control of performing the switching, but the SCADA system will be able to automatically interpret the switching note, and handle it automatically.

For the third project, the better the smart dispatching tool will become, the more it will be able to take work from the dispatcher. In a first phase, the tool will gather alarms and show them to the dispatcher based on priority. Subsequently, the tool will interpret these alarms and propose to the dispatcher which actions he needs to take in order to solve the problem. The third and most ambitious phase is this where the tool first interprets the alarms, and then automatically takes the necessary steps in order to restore the grid. This way, we will pave the way towards a self-healing grid.

19. UNDERSTANDING THE ENABLING ROLE OF BLOCKCHAIN TECHNOLOGY IN THE MANAGEMENT OF DECENTRALISED FLEXIBILITY

A. *Innovation objective & problem to solve*

Problem definition

Current situation for ancillary services reserve and activation:

For the moment, TSOs cover their need for ancillary services via a common tendering procedure.

As a result, in the current process, to be able to participate in that tendering procedure the connecting TSO conducts a prequalification of technical units. The TSO is the only contract partner for the technical unit.

After the technical prequalification a framework agreement between the technical unit and the TSO is concluded. The prequalified minute reserve has to have at least the minimum lot size.

Traditionally balancing power was only requested from large generation units which shifts towards multiple smaller generators in the future. This also includes batteries installed in households or electric vehicles at charging stations.

Impact of the energy transition:

A higher fragmentation of balancing power providers requires a rethink of the current process in order to be able to efficiently integrate and communicate all participants.

With the integration of small BSPs, connected to the distribution grid, information exchange requirements between TSOs and DSOs will significantly increase.

Furthermore settlement processes as well as the costs of technical prequalification and the effort of conducting framework agreements will become more complex and resource intensive.

Besides security of supply and a reliable electricity grid, cybersecurity plays a very important role with increasing number of participants.

As tendering for balancing power and the award of a contract to a BSP uses blockchain technology, it is possible to efficiently implement secure and safe communication of this information among TSOs, DSOs, aggregators and BSPs.

Potential role of blockchain technology

With the help of blockchain solutions and smart contracts, a framework might be established where the integration of small SPs can be automated (verification, communication, settlement).

The activities aim at understanding the technology and the potential of blockchain technology in general and especially the provision of balancing power. This includes in particular responding to the following questions:

- How can the technology incentivise real-time behavioural change among prosumers?
- How can BSP be verified over the blockchain and are there efficiency gains?
- What are technical prerequisites (how to establish a client) for validation at BSP side?
- How do other stakeholders benefit (regulators, DSOs, aggregators)?
- How scalable is the technology?
- Is it fast enough to efficiently communicate with large number of BSP (latency and low throughput)?
- How will blockchain technology ensure data security (using pseudonyms for sensitive data)
- How will settlement process need to change with the implementation of token and exchange to fiat currency

- The benefits of this technology for the balancing process are:
    - Reduction of credit risks and collateral requirements for stakeholders which is especially of benefit for small, decentralised participants
    - Higher transparency of market operation itself (information on the blockchain can be easily shared between all parties)
    - Near real time confirmations and direct settlement.
    - Facilitation of trading, improving auditability and process integrity,
    - Risk reduction of malevolent behaviour (by providing secure data storing)
    - Enabling interoperability through standardised data formats across multiple organisations

Objective

To understand the potential impact of basic blockchain technology, Elia joined the Energy Web Foundation (EWF). In doing so, Elia benefits from early and privileged access to basic blockchain technology and can develop and test applications with up to two years in the market.

In 2019, Elia implemented an initial proof of concept aiming to understand the technology and how it could be implemented in the settlement process. This has already proven than could drastically reduce the time for certifying and onboarding the decentralised flexibility providers (certification of metering device and accelerated contracting). In parallel it can lower the entry barriers for new decentralised players by drastically reducing the entry barriers by limiting the amount of money to be escrowed to the size of a bid and for the time of an activation only. The POC is detailed in the section *Concept and results of POC conducted in 2018/2019.*

Besides this, from this proof of concept, we have identified three challenges for the 2020, the Innovation team aims to:

- Test different solutions to ensure confidentiality;
- Understand how to set up a blockchain token transfer in traditional currency (EUR);

- Understand the legal value of the smart blockchain contract.

Based on the results of these additional testing and feedback from internal experts and peers from other utility companies, Elia will begin developing the next phase of the blockchain test, which should include:

- The participation of several counterparties (DSOs, regulators, aggregators, etc.);
- Direct connection to measurement/activation devices and ensure safe communication.

Impact for Elia: KPIs and/or hypothesis (qualitative and quantitative)

- **Efficiency of the validation process:** Elia will improve the efficiency of the prequalification process as it might no longer request physical present and accelerate the initial data exchange. The use of blockchain technology in combination with smart contract will replace or simplify the prequalification of Balance Service Providers (BSPs). Smart contracts have the ability to replace framework agreement between the BSPs and the TSOs. The use of blockchain technology could completely replace the current process leading to efficiency gains of 30-50%. At the same tame the technology is linked to several technical and organisational perquisites.
- **Access to new sources of flexibility:** Elia will be able to efficiently integrate small units of BSP (household batteries, electric vehicles, heat pumps, etc.) and access to flexibility volumes of about 2.5 GW until 2030/2035.
- **Reduction of settlement period:** The duration of the settlement processes includes complex reconciliation efforts, volume updates and confirmations which will be drastically reduced from three to four weeks today to close to real time.

Use of the results

Support the energy transition						
Improve public acceptance						
Improve the efficiency of Elia						
Improve market design						

In the future, Elia may need more flexibility with much greater granularity (heat pumps, electric vehicles, etc.). A higher fragmentation of balancing power providers requires a re-thinking of the current process in order to be able to efficiently integrate and communicate to all participants. This will magnify the need to enter into contracts with new players, conduct flexibility auctions and settle flexibility transactions.

The current settlement process is not evolving and would result in a massive need for labour. The use of blockchain technology and the smart contract will automate the settlement and put in place a scalable and efficient back office process for flexibility transactions.
In addition, this scalability will reduce entry barriers for new small players by limiting the bank guarantee necessary to participate in the market.

Concept and results of POC implemented in 2018/2019

In 2018 and 2019, Elia implemented a proof of concept (POC) to test the capability of blockchain technology for the process of tendering, accounting and settlement of balancing power. The concept of the POC is briefly explained in this chapter as it is building the basis of the new POC and aims at closing the gaps that have not been covered.

In a consortium between Elia, the Energy Web Foundation (EWF) and SettleMint, the balancing process has been simulated on a blockchain test network. In the test environment the registration of the BSP, the bidding process, the calculation of activated energy and the settlement were implemented (see 56).

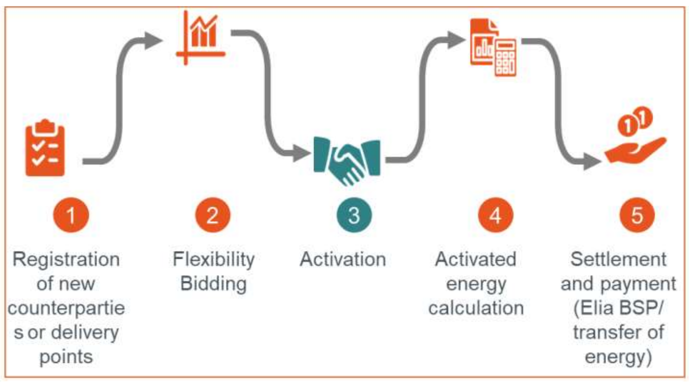


Figure 57 - Process steps of the balancing process that have been simulated on a blockchain test network.

A set of three smart contract were developed to establish interaction between System Operator, BSP and Delivery Point as well as to be able to implement the bidding, accounting and settlement process.

Contract System Operator – Balance Service Provider
In this contract the regulatory rules between the SO and the BSP are defined as well as the details of the contract partners.

Contract Balance Service Provider – Delivery Point
In the second smart contract between the BSP and the DP the metering device is registered and contractual details between the parties are exchanged.

Flexibility bid
The flexibility bid contract is required to define the bidding rules, to measure the provided energy and is the basis for the settlement process.

To activate the smart contracts and to simulate the balancing power tendering and bidding process user interfaces have been modelled (see **Error! Reference source not found.** 57).

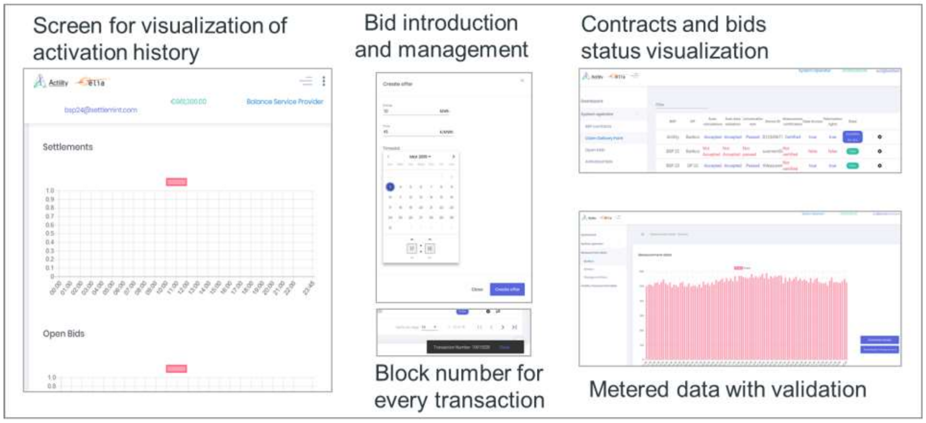


Figure 58 - User interfaces to establish the connection between the bidding process and blockchain technology.

With the help of the POC important learnings have been achieved that unravelled the benefits and the potential of this technology. The main findings can be summarised as follows:

- The blockchain technology is theoretically ready to use which could be proved in the POC simulation environment.
- Smart contracts have been successfully implemented and proven suitable for registration, contracting and accounting of provided balancing power as well as settlement.
- The nature of blockchain technology brings trust via immutability and escrow management. Nevertheless, the transparency of bids and providing pseudonyms for participants require further work in smart contract design to protect access to sensible data.
- The settlement process is accelerated massively. The provided energy is measured and captured together with the balancing energy in a smart contract which allows direct settlement with tokens.

Since the POC was a successful simulation the next step would be to test the application with physical assets in real operation. The use of DLT solutions for activating balancing power requires integrating metering devices with blockchains and adopting the process of prequalification as well as the setting up the framework contracts between TSO and device on the blockchain.

B. *Project definition and planning*

Overall type of the project (innovation phase) and program

Exploration phase

Understand and enable the integration of new, decentralized, assets in the market

Separation into work packages

In order to build up on the already executed POC that ended in 2019 the goal of the follow up is to further develop the POC in [redacted] and [redacted]n order to have a running pilot project in live operation by [redacted]. The following work packages are required to achieve this goal:

- **WP 1: Consortium and project scoping**
    - Setting up a consortium of partners covering e.g. DSOs, BSPs, software developers and provider of blockchain client hardware.
    - Project scoping together with the consortium
- **WP 2: Development of IT system**
    - Defining and aligning on IT system specifications for all process steps (validation, tendering, accounting, activation, balancing and settlement)
    - Develop and update existing IT system. This includes among others:
        - Develop new smart contracts (validation & activation)
        - Adapt and extent the existing smart contracts
- **WP 3: Development of hardware system**
    - Defining hardware requirements (type of client, BSP connection and requirements, etc.)
    - Installation of the hardware client on the device(s) and connection to the blockchain
    - Establish safe communication and data exchange between the devices and the counterparties (BSPs, DSOs and TSOs).
    - Integration of all counterparties in these process steps
- **WP 4: System testing & validation**
    - System testing and quality control (hardware / software interface)
    - Testing of smart contracts with focus on
        - Validation of devices
        - Activation of devices
    - Testing system stability and reliability
- **WP 5: Live operation**
    - Activation of BSPs through smart contracts to support frequency stability

Planning by work package

The goal is to continue testing in [redacted] and [redacted]after the initial experience that ended in [redacted]. With the ambition of a possible integration and implementation during the period 2022-2023.

C. Context/stakeholders in the project

As was the case for the initial POC, the following will be involved:

- Technology partners that will be selected via request of proposal (example, in the last project, Elia partnered with SettleMint).
- Elia will also leverage the EWF experts (in technology, business and legal), but also the network of the other affiliates including other utilities that are developing blockchain applications (e.g. ENGIE, Stedin, Shell) and also specialised start-ups (e.g. Flexi-Dao, Oli).

As in this next phase Elia is aiming to test the use in real conditions, Elia will onboard other players from the value chain: DSOs, suppliers and aggregators.

D. Value development plan

How the project contributes to the strategic and innovation objectives

As demonstrated in the initial proof of concept, blockchain technology can make the onboarding process of new decentralised flexibility efficient (from a few days to a few hours/minutes). It is then completely in line with the strategic objective of delivering an affordable electricity supply while integrating new flexibility resources to cope with the increased system intermittency.
This is reinforced by the fact that blockchain technology has the potential to facilitate the integration of new flexibility means thanks to much easier escrow management.

Implementation plan

Blockchain technology is still at early stage of exploration for Elia, and the implementation plan has not been defined yet. The goal from [redacted] onwards would be to start implementing the use cases that are validated among the different opportunities (certification, settlement process, etc.)
The implementation plan will be setup as soon as the use case is validated.

Potential next steps

In parallel with the use case for blockchain technology relating to the value chain associated with flexibility activation, the technology could also provide added value for Elia's other businesses (for example, certification of the maintenance activities).

20. DEVELOPING TRAINING COURSES IN VIRTUAL REALITY

A. Innovation objective & problem to solve

Problem

The digitalisation of the energy sector is moving forward at a phenomenal rate with always new technologies or processes to learn (e.g. HVDC substation, Offshore substation…). In parallel, there is always needs for additional/new resources like subcontractors to be trained efficiently in order to be quickly operational.

At Elia, we are then continually on the lookout for new teaching methods with a view to both encouraging new, positive behaviour and promoting learning.

Working in a high-voltage environment is dangerous and leaves no margin for error. As a result, it is difficult to place our staff in the kind of hazardous situation they might encounter during their career. 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 the quality of our training courses.

This year, we decided to focus again on the technical aspect of virtual reality, which has now reached an appropriate level of maturity for Elia to make a start on the initial scenarios that will be used in a training course for our field staff.

This choice of technology also sends a strong signal to our staff that the technological revolution is under way in their profession and that it is essential that they learn how to use new technologies so that they can carry out their duties properly.

Objective

Virtual-reality e-learning is an immersive process that will soon be mature enough to be used in the initial projects under production. It also has the following benefits:

- It enables our staff to experience dangerous situations in the safe environment of a simulation.
  Use case: Field staff often report that the invisibility of the danger posed by electricity is a major risk. Therefore, we want our staff to experience this invisible danger in simulations. For example, testing staff's responses to finding a colleague unconscious in an electrical danger area or seeing a vehicle enter a DL/DV area.
- It enables our staff to experience situations requiring them to use their soft skills.
  Use case: If a contractor is climbing a pylon without following the rules, the member of staff must be both authoritative and empathetic to encourage the contractor to ensure their safety by using the equipment provided for this purpose.
- It enables our staff to practise safety measures that need to become reflexes rather than just learned.
  Use case: Before operating equipment, staff need to comply with the colour-coded safety instructions and be able to make the right decisions in hazardous situations.
- It enables our staff's common sense to be tested in situations where it is impossible for them to carry out their work.
  Use case: For example, situations that have already had tragic outcomes in the past where staff are unable to perform their work for some reason but want to start work scheduled for the following day, when their safety may not be guaranteed. We will present our staff with these choices.

Impact for Elia: KPIs and/or hypothesis (qualitative and quantitative)

It is difficult to assess training using quantitative indicators. We will try to elaborate on these indicators and will discuss qualitative indicators in more detail.

Quantitative KPIs

FTE reduction among trainers

Bearing in mind that digitalisation is making our business more and more complex and the grid is becoming increasingly distributed, we will be able to limit the growth in the number of trainers required. We believe that from 2021 onwards, the growth in the number of trainers should be reduced by [redacted].

Speed of access to very specific training

When staff register for classroom-based courses, the course may not start for a number of weeks. Moreover, courses are often held considerable distances from the member of staff's workplace, which may mean they have to waste a lot of time travelling there. Finally, experienced staff will only be interested in part of the course, not all of it. Two KPIs can be looked at here:

- The waiting time for a course could be reduced from several weeks to **a maximum of a few days.**
- The time spent training in a specific topic could be reduced from a day (or half a day) to just **a few hours**.

<u>Qualitative KPIs</u>

Below, we describe the indicators in terms of their contribution to the strategic objectives (Sos).

Very poor: has a very negative impact on the Sos

Poor: has a negative impact on the Sos

Quite poor: has a slightly negative impact on the Sos

Quite good: has a fairly positive impact on the Sos

Good: has a positive impact on the Sos

Very good: has a very positive impact on the Sos

The amount of training undertaken

This could increase in the same way as e-learning because, as indicated above, experienced staff would be more inclined to take a course on a very specific subject rather than a comprehensive course on subjects they are already well versed in.

Indicator: quite good

Accelerated behavioural changes

Immersive simulations enable staff to become aware of the dangers more quickly and trigger behavioural changes.

Indicator: good

Repetition of safety actions

Learning by repetition enables staff to approach these tasks with greater peace of mind and therefore reduce the risk of errors while increasing productivity.

Indicator: very good

Relationship with the trainers

The more independent we make our staff in terms of training, the less contact they might have with the experts. This could pose a risk and needs to be addressed.

Indicator: poor

Mitigation of risk: We will keep offering standard courses to foster relations between field staff and experts (e.g. the training centre).

Use of the results

Supporting the energy transition						
Improving public acceptance	See the next stages of the project					
Boosting Elia's efficiency levels						
Enhancing market design						

The energy transition means that our grid will become increasingly spread out and as a result will become more diverse and more complex. To meet the new flexibility needs, we are already seeing changes in our substations, which are swapping cables for an Ethernet network.

This means that field staff will have to deal more often with equipment they have never seen before than they did in the past. Being able to practise in a simulator and carry out the work in virtual reality will make it easier to arrange staff's schedules because it will no longer always be necessary to have a member of staff who is experienced in the relevant technology. The time required to carry out work in the field could also be reduced due to the repetition of a specific task.

Facilitated training will increase staff's skill levels while also making our grid more resilient and further reducing the risk of an accident involving our staff. The four main anticipated benefits for training are:

- reducing the risk of accidents;
- increasing our staff's expertise;
- reducing the digital and technological gap facing our internal resources;
- changing behaviour.

B. *Project definition and planning*

Overall type of the project (innovation phase) and program

Exploration phase

Develop the digital worker tools and capabilities

This transformation programme is part of the training strategy the company has adopted. In 2017, Elia produced an initial proof of concept to increase the maturity of virtual reality technology. We are now ready to integrate training scenarios.

In 2019, we met potential partners and identified a company offering an advanced programme that would enable us to set up courses quickly and easily.

In September 2019, a workshop was held with field staff from the Safety and e-Learning Departments to decide on the initial scenarios to be implemented. During the workshop, we defined an implementation model based on the common theme of the substation visit. Based on this substation visit, the first phase involves the 'player', i.e. the member of staff wearing the virtual reality headset, being taken through various scenarios:

- Demarcation problem in the substation
- Danger due to proximity with high voltage (e.g. equipment entering the area)
- Risk of a fall from height with unsuitable equipment (soft skills)
- Repeated start-of-work scenarios, with colour-coded safety instructions

We are expecting to see results by [redacted]

Phase 2 will be based on a comprehensive training programme for a field agent with a specific safety role.

Implementation of Phase 2 will start in [redacted] and should finish in [redacted] if the Phase 1 tests are successful.

Comment on the scenarios

We thought long and hard about the scenarios we chose, which do not currently correspond to a training programme for a specific role because we had various objectives for Phase 1.

Creating scenarios with aspects that are relevant for field staff will enable them to experience dangerous situations, enhancing their training programme. Moreover, by choosing scenarios that are accessible to a lot of people in the field, we want to make them aware of the risks and indicate that all Elia's businesses will be making increasing use of technology as time goes on.

Separation into work packages

We will use a sprint methodology based on Agile project management methodologies to ensure that the implementation meets the needs of our businesses and to secure the approval of the staff who will eventually be trained using this technology.

Sprint 01: modelling the site

Carry out a survey on site (take pictures, scan some equipment, etc.).

Model a high-voltage substation based on existing plans.

Model an electricity pylon.

Model characters (digital people dressed in Elia colours and having the right equipment).

Sprint 02: developing the PPE scenario on pylons

A contractor climbs up a pylon without the necessary safety equipment.

The aim is to detect this dangerous situation and stop the contractor in time. The member of staff undergoing training will need to demonstrate the required skills to persuade the contractor to return to safety.

The member of staff will have to indicate which PPE the contractor is missing. After passing the test, the member of staff will also be able to climb up the pylon to perform an operation that was interrupted by the sound of thunder.

Sprint 03: developing a non-demarcation scenario

The member of staff is unable to reach their workplace because there is no demarcation on site. The member of staff will be assessed based on whether they make their way to the work area despite not having to pass through demarcation.

The user will have to press the STAR button and will be presented with a series of options, not all of which are appropriate.

Sprint 04: developing an X-ray view of the potential danger in and around live objects

Augmented view that can be activated in the DL/DV area around electrical areas, enabling dangerous areas to be identified and safe distances to be determined.

Sprint 05: developing the main scenario of the simulation

The member of staff arrives by car and needs to go to the entrance of the high-voltage substation.

Once the member of staff has crossed the barrier, they must lock it behind them.

The first stage involves complying with the demarcation.

Along the route, the user should notice the dangerous situation presented.

360° view of the substation: check the situation and demarcation.

The member of staff will be asked to read the permit to work and take the necessary measures.

The member of staff should be able to move throughout the site to check that everything is compliant and conduct a risk analysis.

Interaction with the go team and animation.

Sprint 06: developing an 'unexpected lock-out card' scenario

A lock-out card attached to one of the pieces of equipment being worked on is not compliant and is preventing the operative from carrying out the work. The member of staff will have the option of starting the work the following day, but this is the wrong choice because their safety may not be guaranteed.

The aim is for the user to contact the local safety officer (CSL/LVB) to determine the right course of action.

Sprint 07: adding details to the virtual environment

Model the scenery (route with vehicles passing by, high-voltage lines, vegetation, fence, etc.)

Model interactive components (demarcation, truck, etc.)

Sprint 08: adding an exception: danger in the proximity of electricity

We simulate a scenario where a member of staff is unconscious in an electrical danger area so that the member of staff being trained is put in a dangerous situation due to the proximity of electricity. The aim is for staff to take the appropriate safety measures before approaching their colleague in distress while staying out of harm's way themselves.

Sprint 09: adding an exception: sound of a discharge

The sound of a discharge can be heard coming from a piece of equipment. As this indicates that there is the risk of an explosion, the member of staff will have the choice between performing maintenance on the piece of equipment or getting to safety and heading for the assembly point in the event of an accident.

Planning per work package

The following schedule sets out the progress of implementation:

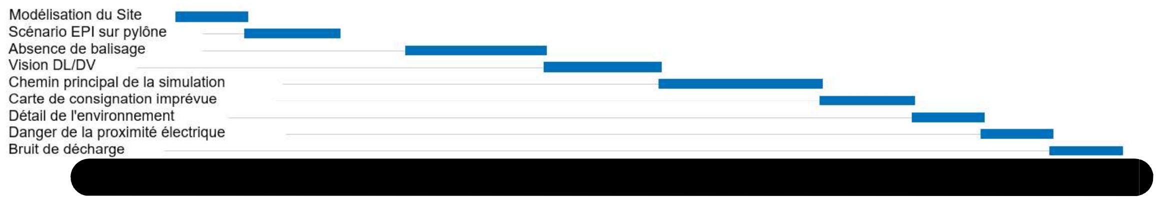


Figure 59 – Planning of implementation of Virtual Reality trainings

C. Context/stakeholders in the project

The **Safety Department** will be able to raise Elia employees' awareness of potential risks in an immersive way and reduce the number of accidents in line with the Go for Zero target.

This training will also help us to make our **contractor** partners more aware of the hazards associated with working near high-voltage equipment.

The **Training Centre** will be able to target sessions at specific groups and improve the effectiveness of their training as staff will be able to use virtual reality (VR) to train throughout the year.

We will also have a tool for attracting **new talent** when hiring staff, showing potential applicants that Elia is committed to promoting safe learning using new technologies.

When our e-learning platform was launched, we made some assumptions about training formats which turned out to be unsuitable. But based on user feedback from direct experience with the tool, we reduced the length of the sessions from over an hour to just a few minutes. While we have learnt some important lessons from e-learning, we will continue to face the same kinds of issues, which will require us to make rapid adjustments. Throughout the implementation phase, we will test formats and usability with our **field staff** so that we end up with a product that is tailored to their needs.

We hope that future versions of this tool can be used in a 'public acceptance' context to bolster **residents'** support for new projects by immersing them in the changes we will be making to their local landscape.

D. *Value development plan*

How the project contributes to the strategic objectives

Being such a versatile technology, virtual reality could help to meet a wide range of objectives. In the area studied, we can clearly see that some objectives will be positively impacted by this initiative, first and foremost of course improving operator safety.

By providing a simulation environment that allows our staff to experience hazardous situations and practise the correct measures, we are contributing to a system of safety training that will reduce risks in the field.

Go for Zero is a priority for Elia, and so we intend to be fully aligned with this vision.

In keeping with another major strategic goal at Elia, that of becoming a Digital TSO, we are offering a digital tool that allows our staff to practise work-related actions and improve the quality of their work while reducing the amount of time spent in the classroom. This means they don't have to wait for a course to become available or waste time travelling to courses.
It should be noted that VR training will be used alongside traditional training as a way of boosting our staff's expertise levels.

We also have an opportunity to change the company's culture and mindset by sending out a strong signal that the digital revolution affects us all and is penetrating to the very heart of our business. We want to show that technology is there to help us improve in terms of skills and productivity. The message is that we need to be open-minded towards digitalisation now so that our staff will be willing and able to use the tools they need in the future.

Talent management is another key factor, of course. At recruitment fairs, the image conveyed by this type of initiative really propels us to the forefront, demonstrating Elia's ability to be a top-level player in innovation in all areas, including training.

Link with Elia's other innovation objectives

- Continuation of the SarqaVR prototype (test project completed, not in this report).

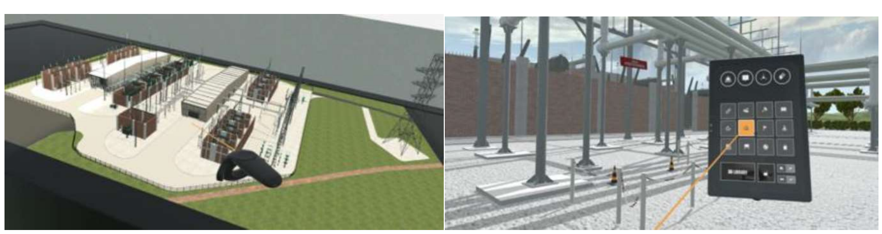


Figure 60 - Example of virtual reality substation

- Hazard alert when entering a dangerous electrical area using EMF sensor (16). We are working on the introduction of a wristband that alerts staff when they are near a dangerous electrical area.

Figure 61 - EMF sensors

Potential next steps

If virtual reality is successfully implemented as part of the training programme for a specific safety role, we will extend it to other training pathways.

The Nemo HVDC converter station, where access is prohibited and working time must be kept to a bare minimum, is a good example of a facility where VR could be usefully deployed to reduce the maintenance time.

Using VR to show local residents how new Elia projects will look when completed could help promote public acceptance of such projects.

21. AMEX FOLLOW-UP

A. Innovation objective & problem to solve

Problem & objective

Through its AMEX programme, Elia optimises the entire life cycle of assets, from the design of the asset and the operation and maintenance phase to the decision to dispose of the asset at the end of its life cycle, by analysing its condition and performance levels and the costs and risks involved.

The program was launched in 2016 and was developed based on the principles of ISO 55000 and reliability-centred maintenance.

The AMEX program is divided into six phases, each of them lasting around six months and focusing on one or more asset categories (transformers, cables, overhead lines, switchgear, etc.). The first step is to develop a comprehensive overview of the current condition of the assets, including their performance level, costs and practices. Detailed risk analyses are carried out to fully understand asset failures and behaviour. Based on this knowledge, a customised strategy is developed for each asset category. The implementation of measures to improve quality, optimisation and reliability is closely monitored.

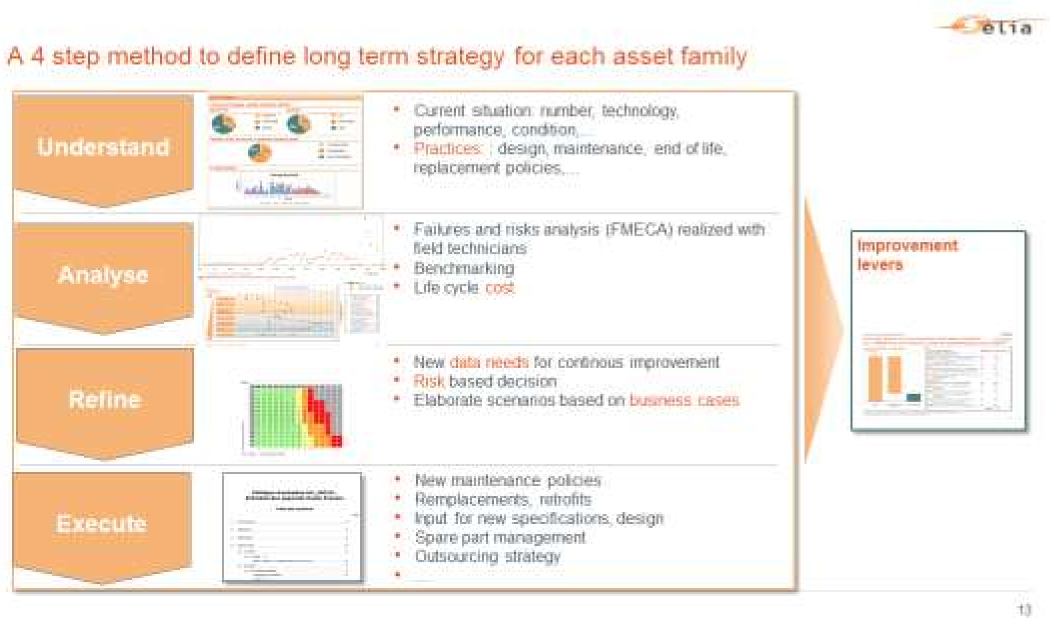


Figure 62 – Methods for assets

Innovative character

The AMEX program is innovative in a number of ways:

- New methodologies that have never been used before have been implemented (such as AMDEC (Analyse des Modes de Défaillances, de leurs Effets et de leur Criticité), which analyses failure modes and their effects and criticality), as well as innovative statistical analysis methods.
- Innovative tools have been used (drones, IT platform, remote monitoring, etc.).
- Decision-making methods based on the risk and the condition of assets that are new to Elia and have so far only been rarely used by other infrastructure operators across the world have been propagated. Using a 'health index' required the development of new inspection methods, data-collection and processing platforms, formulas and data-processing procedures. Risk analyses also involve assessing the effects the loss of an asset will have on systems, which remains a very underdeveloped concept.
- Moreover, the new features like the health index are a prerequisite for the development of even more innovative methods such as predictive maintenance, which requires sophisticated models to be developed and in-depth knowledge of asset-operation deterioration modes.
- The integration of new technologies (such as IEC 61850) requires us to develop new skills and therefore to thoroughly review our training methods.

Impact for Elia: KPIs and/or hypothesis (qualitative and quantitative)

The programme has the following major overall objectives:

- review maintenance policies to reduce OPEX;
- between [redacted], lower CAPEX costs by around [redacted] (postponed or avoided CAPEX) for investments related to replacements, mainly by extending the life cycle and better estimating risks;
- reduce grid unavailability by optimising maintenance policies (scheduled power cuts) and improving asset reliability (unscheduled power cuts);
- maintain an optimal level of safety at all times for our staff and third parties.

The Management Committee has validated these objectives.

These objectives are reflected in each phase of the project depending on the relevance of these aspects to each asset category. The specific objectives are recorded in a project charter completed by the asset fleet manager at the start of each phase and validated by the steering committee.

An example of a project charter is shown in Figure 64.

WAVE 1

AFS AIS

The AIS Asset Fleet Strategy aims to determine which activities need to be performed in priority to build, operate, maintain and dispose. The study activity will be divided into four phases:

- The phase "**understand**" will give an overview of the asset fleet (population, age, performance and health) and the current practices.
- The phase "**analyze**" will aim to perform the FMECA analysis for core family members, to give a benchmark of maintenance and testing frequency with other TSOs, to analyze the failure patterns and to identify quick wins.
- During the phase "**refine**" we will define the data needs to improve our models for failure capture, health index definition, cost control,...
- The phase "**execute**" will propose a new strategy for each asset in term of replacement policy, end of life criteria, maintenance policy, testing,... based on risk and health criteria. Some quick wins will be identified and implemented before the full implementation of the wave.

After the four phases of the study, implementation will occur during a 9 to 12 months period where all trainings, procedures, processes, systems adaptations,... will be realized. Implementation will be described in another project charter as detailed implementation deliverables will be known at the end of the study wave.

RESOURCES

Name	Role	Availability
[redacted]	Category leader	60%
[redacted]	Stream Leader	20%
[redacted]	Coordination	30%
[redacted]	FMECA analysis	10d
[redacted]	Technical Expert	30%
[redacted]	Technical Expert	30%
[redacted]	Technical Expert	20%

MILESTONES

Name	Time
Finalized description of the current asset fleet strategy	12/02/2016
Validated outcomes of FMECA-studies	11/03/2016
Validated data model asset fleet	06/05/2016
Validated new asset fleet strategy	24/06/2016
Start Implementation	30/06/2016

MAIN DELIVERABLES

- Equipment types inventory and structure
- AS IS description of asset fleet strategy
- FMECA analysis for most critical equipment types
- Data model for failure, health index, costs
- TO BE description of asset fleet strategy
- Quick wins
- Action list for implementation (referring to what should be done to implement)
- Determination of minimum spare parts levels of critical spares
- High level outsourcing analysis: criticality vs provider maturity
- Gap analysis of the current training plan
- Overview of new and obsolete maintenance activities
- UME analysis

KEY RISKS

- Resources availability
- Adaptation to new project organization
- Change in requested level of detail and quality
- Timing in function of the very large scope

TARGETS

- Tour poste client: -0.5 FTE /year
- UME for preventive maintenance time: -10% (4 FTE) / year

OUT OF SCOPE

- Developing new outsourcing strategy
- Optimization current spare part stock management and warehouse cleaning

In scope of implementation wave:

- Organizational implementation of the new strategies and policies
- Set up training documentation and manuals
- Adjustments of tooling and operational documents (checklists, manuals, etc.)
- Communication to and training of personnel regarding new asset fleet strategy
- Savings linked to organization efficiency

Figure 63- Example of project charter

At the end of every wave (project phase examining one or more asset categories), a number of improvement measures were agreed on and implemented (some of these are still being implemented).

Examples of measures (non-exhaustive list):

- For air-insulated switchgear (AIS) substations, maintenance tasks with low added value or that do not cover a significant risk have been dispensed with;
- A retrofit campaign will delay the replacement of power transformers (between 2017 and 2027, 120 on-load tap-changing (OLTC) transformers and 40 Shell transformers will be renewed for more than 16 years);
- For gas-insulated switchgear (GIS) substations, the remote monitoring of certain values is being assessed (mainly the density of SF6 compartments). Pilot projects have been carried out;
- Switching cabinets are being replaced with a view to moving from 185 to 235 cells per year without additional CAPEX; this measure is related to the SPACS project, which is documented below;
- For overhead lines, AMEX will enable notable efficiency gains to be made by applying more suitable management methods and above all by using new technologies like LIDAR;

- The AMEX methodology has also enabled us to question the maintenance programme proposed by our supplier for new Allegro HVDC facilities, improving the detection of any failures and making inspections more thorough during maintenance work and facility restarts, so that we can meet the very ambitious availability objectives;
- The health indexes were developed for all the most critical asset categories. They are managed via a new management platform for large quantities of data and are used to optimise decision-making processes related to maintenance and replacements.

Use of the results

Supporting the energy transition						
Improving public acceptance						
Boosting Elia's efficiency levels						
Enhancing market design						

AMEX has transformed our maintenance policies as we have shifted from a mainly time-based approach to one based more on conditions and risks, minimising the additional costs associated with the growing complexity of the grid and its management, while improving reliability and never compromising safety.

By producing tailored maintenance strategies that are optimised for each asset category, AMEX helps Elia better optimise how it monitors the reliability and availability of the grid, facilitating the upcoming energy transition.

B. *Definition of project and planning*

Overall type of the project (innovation phase) and program

Pre-exploitation phase

Using analytics to optimize the grid development and O&M to enable better flexibility and efficiency

Separation into work packages

AMEX started in 2016, with six waves planned. Each wave focuses on one or more asset categories, and is divided into two main stages: the first stage involves defining the strategy for each asset category (six months), while the second stage is all about deployment (length of this stage dependent on the fleet). We are currently working on waves 5 and 6, whose completion is expected by late 2020.

Considering that AMEX generates significant changes to working methods in the field, the implementation of the improvement measures resulting from the waves was split into various releases. Each release focuses on one or more aspects of processes in the field: maintenance of high-voltage equipment in substations, inspections of power lines, lopping and clearance, painting, low-voltage equipment and protection, etc.

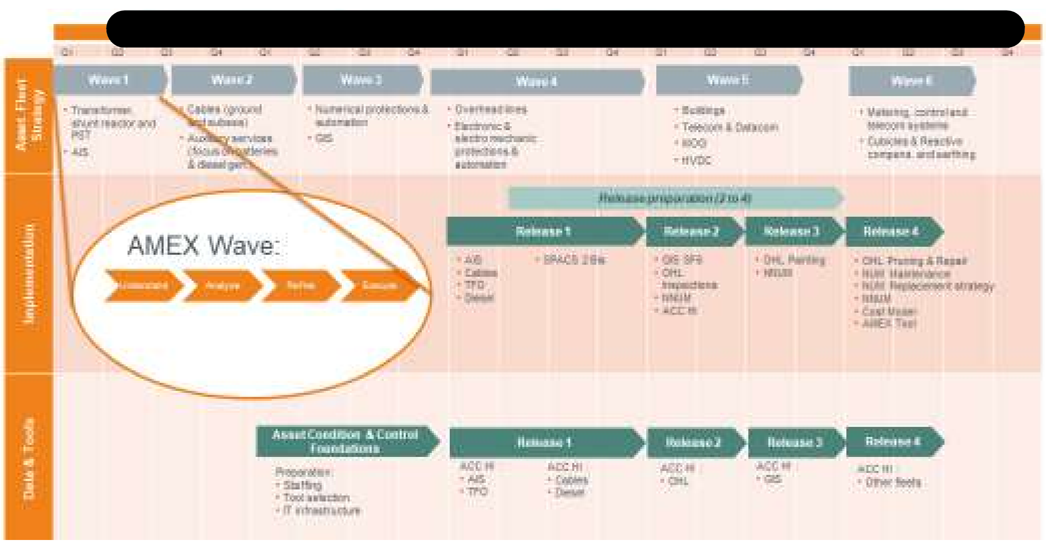


Figure 64 – Waves of Amex project

The following assets are assessed in each wave:

Wave 1:

- Power transformers, shunt reactors and phase shifters
- Air-insulated switchgear (AIS) substations

Wave 2:

- Cables

- Batteries
- Diesel generators

Wave 3:

- Digital automation and protection (latest generation)
- High-voltage (>70-kV) gas-insulated switchgear (GIS) substations

Wave 4:

- Non-digital automation and protection (old generation)
- Overhead lines

Wave 5:

- Buildings
- Telecom equipment
- HVDC systems
- Offshore facilities

Wave 6:

- *Metering*
- Remote surveillance systems
- Reactive compensation
- Earthing

Planning by work package

Each wave has a standard duration of six to nine months. Each wave adopts a methodology that is split into four phases, as described in the figure 66.

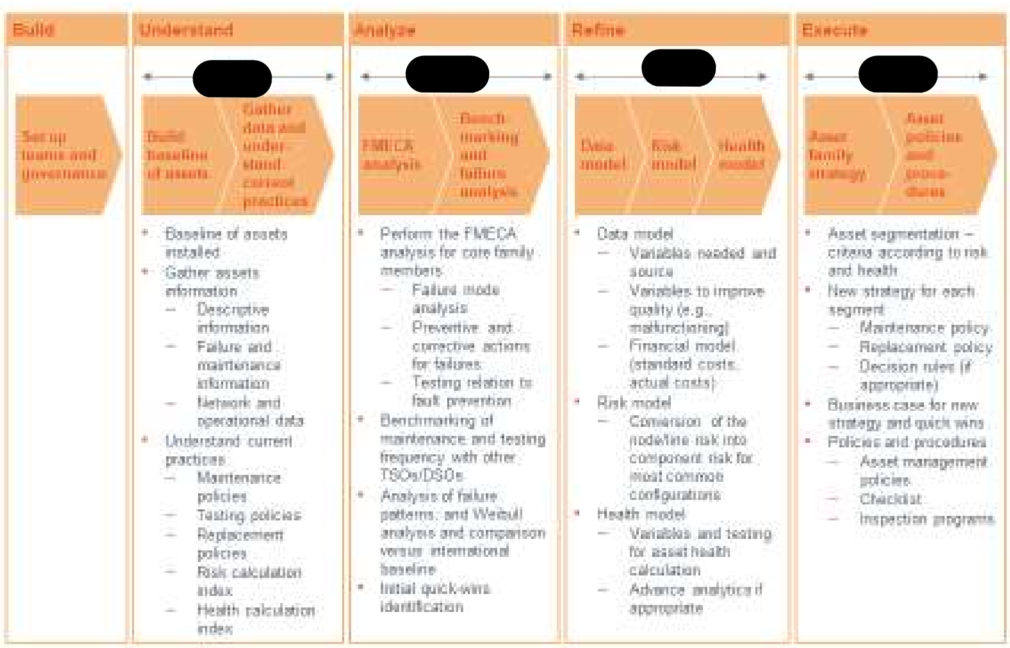


Figure 65 – Planning of AMEX work package

A wave's final deliverables are:

- a strategy for managing the asset fleet in question throughout all stages of the life cycle: specifications for the design, purchasing strategy, installation and commissioning management, operation, retrofit and maintenance strategy, decommissioning and end-of-life management;
- a set of improvement measures aiming to enhance current fleet management in terms of cost, reliability, use of internal resources and the need for power cuts.

Project governance

In view of the challenges for Elia, a strict project management method is applied. At the start of each phase, the detailed scope and schedule are defined by that phase's manager. The teams are established and the time required freed up in their work programmes. Each person's roles and responsibilities are determined (see the figure 67).

	Role during the AMEX transformation
Project Lead	• Leads project and makes decisions on project direction in line with CODIR • Validates deliverables regarding the fleet strategies and asset management processes • Follows up weekly on program and execution
Program Manager and PMO	• Overall responsibility of program execution and targets achievement • Transversal coordination between streams • Planning, follow-up, reporting, support for communication material • Challenge deliverables before validation
Stream Leader	• Overall responsible for execution of workstream • Report progress: e.g., savings targets, monitor measure delivery • Stream coordination, accountable for stream deliverables • Overall reporting requirements of PMO
Category Leader	• Overall responsibility for the execution of the fleet • Technical profile
Expert	• Provide expertise on asset life cycle activities, failure causes, technical standards, … • Give advice on new policies feasibility, work methods

Figure 66 – Roles during AMEX project

Management closely monitors the project through various coordination and validation meetings. The steering committee consists of programme management, the senior manager of the main department affected and two directors. Reports are compiled regularly, up to the level of the Management Committee.

	Core Team	Impl. Core Team	Steerco	CoDir
Frequency	• Every week	• Every month	• Every two weeks	• Twice per wave
Agenda	• Review progress of the wave • Problem-solve issues • Approve conclusions	• Review progress of the implementation • Problem-solve issues • Approve conclusions	• Update on progress • Set project direction • Validate conclusions • Support problem-solve issues	• Update on progress and conclusions • Validation of high level direction

Figure 67 – AMEX project governance

At follow-up (core team) and validation (steering committee) meetings, discussions are structured to ensure that all the important points are covered. The results are monitored through KPIs and progress summaries. The sub-project manager regularly presents items requiring validation or in-depth discussion. All decisions are recorded in a report.

Here are some examples of material presented at these meetings:

[redacted]

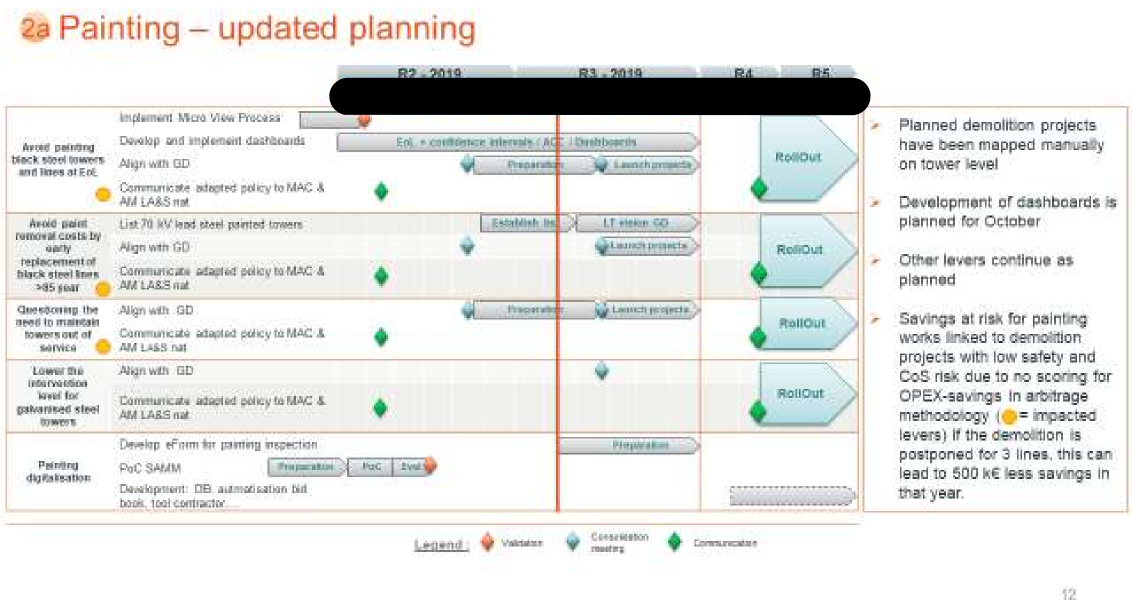


Figure 69 – Schedule for painting workstream of Amex program

Operationally, the project is managed by applying a simplified agile method tailored to non-IT projects (daily check-ins, short-term deadlines, daily task monitoring, frequent touch points, team pulse barometer and self-assessments carried out by project members).

The methodology is documented in its entirety in a blue book that ensures that each phase is carried out in accordance with the same quality standards. For your information, this blue book includes:

- the project context and vision and goals;
- the AMEX approach;
- the programme organisation;
- the detailed step-by-step methodology;
- the day-to-day activity plan;
- the description and templates of deliverables;
- the relevant sources and the input needed;
- the key training modules;
- the sustainability infrastructure;
- the communication toolkit;
- the routine.

C. Context/stakeholders in the project

We have conducted comparative analyses regarding the reliability of certain assets and their maintenance intervals. Apart from this, the approach is purely internal within Elia.

D. Value development plan

How the project contributes to the strategic objectives

The AMEX programme dovetails perfectly with the Assets Division's strategy and makes a significant contribution to the strategic objectives.
Management's vision is summarised in the following image, called the *House of Assets*.

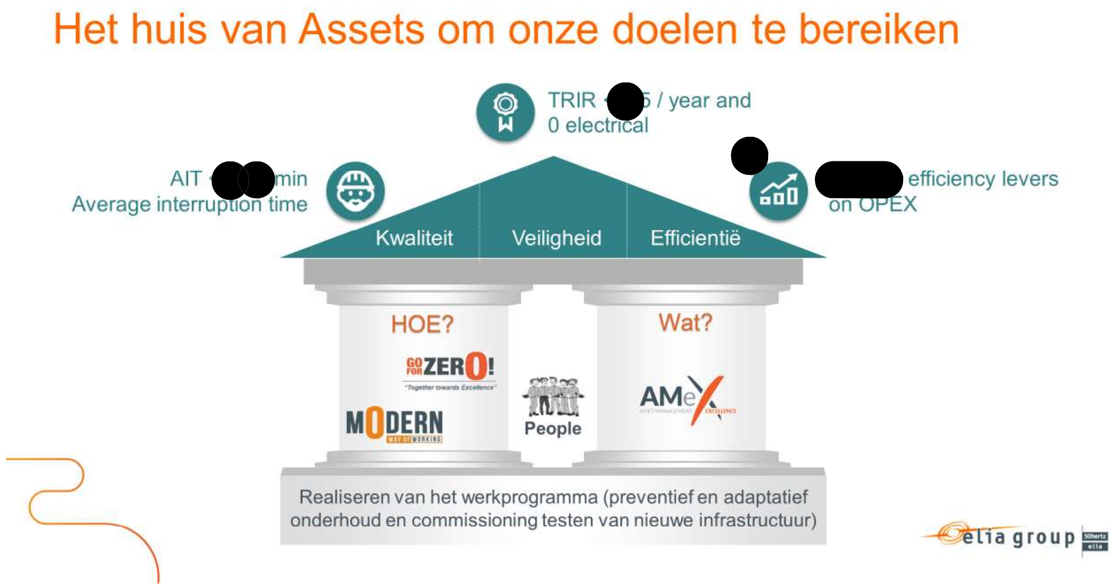


Figure 70 – AMEX in the context of the other Asset Management projects

Link with Elia's other innovation objectives

The AMEX method has actually initiated many other projects at Elia: Asset Condition and Control (ACC), overhaul of the malfunction report process, overhaul of checklists, digitalisation of inspections, and so on.
AMEX is closely related to a host of other projects, particularly in the context of digitalisation: digital solutions providing IT solutions to improve maintenance and tactical decision-making, the development of real business intelligence...
Moreover, AMEX is connected with other projects focusing more on the substance of our concepts like enhanced multidisciplinary.

Implementation plan

See figure 70.

Potential next steps

AMEX highlighted the need for additional analyses to be performed after identifying future problems (emulation of TDM over IP, etc.).

At the end of the project, the new practices should continue to be applied in the organisation, and the continuous-improvement philosophy should be embraced in the long term. That is why the final phase of the project is accompanied by an initiative called 'AM sustainability'. The aim is to incorporate new methods into the day-to-day activities of asset managers.

In conclusion, the AMEX project is transforming the Asset Management Department. It has enabled asset managers to develop methods to better identify risks, detect potential problems much further upstream and be able to prioritise them.

22. UNDERSTAND THE POTENTIAL OF SMART IMPLICIT PRICING TO INCENTIVISE PROSUMER PARTICIPATION

A. Innovation objective & problem to solve

Problem

With the penetration of renewable, the decommissioning of big power plant unit and the electrification of the consumption, the system operator is facing new challenges to keep the grid balanced and reliable. At the same time, more and more flexibility is available on the prosumers' side (EVs, batteries, electrical boilers, etc.) and this flexibility is not easily accessible to the system operator.

From the prosumers' perspective, the electricity landscape is pretty complex to understand. Most of them do not know (and do not want to know) what happens behind the scenes and just need the light to turn on when they flick the switch.

The problem statement is then: how can we get the consumers to support the system operators to keep the grid balanced and reliable by providing their available flexibility in simple way and affordable?

Objective

This project aims to put in place new mechanisms to capitalise on the flexibility of grid users for the frequency control – both major industrial players and residential customers connected to the local grid. Many pilot projects explicitly address the issue of capitalising on flexibility: an energy manager, or energy management system (EMS) manages the relationship between the need for and the provision of flexibility at community level (micro-grid model). This project takes a more implicit, less intrusive approach, involving sending consumers information – such as a price signal (or another type of signal, such as a CO_2 signal encouraging consumption when green energy is being generated) – to which they respond by adjusting their consumption accordingly. At the heart of this project is the concept of 'implicit flexibility', i.e. flexibility associated with a price signal that encourages consumers to respond in a way that benefits the electricity system and that puts consumers – especially residential customers – at the heart of energy management.

How can these implicit mechanisms be achieved? This project consists of four parts, which together aim to fully and consistently capitalise on consumer flexibility based on the implicit flexibility model:

1. the development of **'smart node'** technologies for home use: a gateway box enabling end consumers to respond automatically to price signals with their flexible appliances (e.g. electric water heater);
2. the development of **algorithms** to generate different price signals for various grid stakeholders; technologies to allow them to notify end consumers of their need for flexibility: this aspect involves studying how best to aggregate the various sometimes contradictory price signals into a single such signal;
3. the development of technologies enabling the full, secure and transparent

settlement of the process: these technologies must make it possible to validate individual consumers' responses after the event and ensure that appropriate remuneration is provided for the flexibility supplied by the various stakeholders;

4. an acceptability and **user recruitment study** for the implementation of a pilot project involving around 100 residential customers in Wallonia, with a view to demonstrating the operation of the tools that have been developed and proving their value.

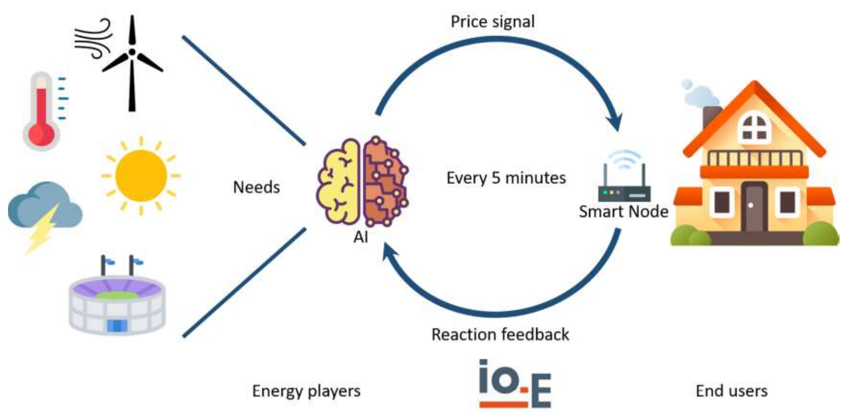


Figure 71 - Principle of AI for smart pricing

Therefore, innovation plays a key role in this project. Each part of the project revolves around the development of new software and algorithm solutions using cutting-edge techniques such as machine learning, analytical techniques for extracting value from large data sets, and blockchain technology.

Impact for Elia: KPIs and/or hypothesis (qualitative and quantitative)

As a grid operator and market facilitator, Elia is interested in understanding and testing dynamic transmission tariffs with a view to responding to the grid's needs and constraints. As far as constraints are concerned, several aspects could be tested:

- reduction in the system imbalance in real time;
- use of market mechanisms to resolve congestion problems.

Balance on the grid is currently maintained by concluding contracts for reserves. Even if these reserves are not activated, they generate a reservation cost that is passed on to all end consumers. The intermittent nature of renewable energy means that the volume of the reserves for which contracts have been concluded must be proportional to the quantity of installed renewable energy. Given the worldwide objectives of limiting the rise in global temperatures and therefore of implementing the energy transition, a high penetration rate for renewable energy will also mean that reserves will have to be increased to maintain grid balance.

Elia hopes to enhance the liquidity of the reserve market through the developments being implemented by this project, thereby limiting the costs associated with increasing the volume of the required reserves. When our infrastructure's capacity does not allow us to transfer energy because the transmission volumes are too large, our grid is considered congested. This issue may be addressed in a number of ways. The grid topology may be changed to resolve the problem, but if this is not enough, other mechanisms, such as energy redispatching, must be activated. This entails reducing the amount of energy being generated in one location and increasing it in another, thereby easing congestion. However, implementation of this mechanism is costly, since it involves activating a volume of energy (which may or may not have been reserved). The reduction in system imbalance and the efforts to control the cost of congestion management will be passed on to end consumers in the form of lower bills.

As a summary, during this project the consortium wants to validate several hypotheses.

User engagement and available flexibility:

- An assessment of the installed flexibility will be carried out via the website www.checkmyflex.be. The trade-off involved in defining the appropriate level of information versus the accuracy of the assessed flexibility will be investigated.
- We also want to understand if/how the users are ready for this new approach of the energy and how we could best engage with them with a smart pricing concept

We want to test the technical feasibility of the solution:

- Ensure that we have the right price for the right flexibility (validate the artificial intelligence algorithms transforming the desired reactions into a price signal).
- Ensure that a smart node device can adequately use a price signal and transform it into a control signal to the appliances, also considering the local constraints and user comfort settings.

Use of the results

Supporting the energy transition						
Improving public acceptance						
Boosting Elia's efficiency levels						
Enhancing market design						

This project will give Elia a better understanding of the price sensitivity of decentralised flexibility, thereby enabling Elia to better adapt the price signal it sends to prosumers with a view to triggering the response required to support the grid.

B. *Project definition and planning*

Overall type of the project (innovation phase) and program

Exploration innovation

Understand and enable the integration of new, decentralized, assets in the market

Separation into work packages

The project's implementation is divided into five parts:

WP 1: Home technologies:

This part of the project aims to develop a special technology package for end consumers to make it easier to activate their flexibility. It will do so by helping them understand the technical potential of flexibility activation and how it could benefit them and by automating the operation of their flexible appliances based on price signals (while leaving them in control of the situation) so that they can derive maximum benefit from this without compromising their comfort levels. This will entail developing:

1.1. a smart control box to be installed in the home, the smart node; it must be capable of receiving price signals and translating them into relevant orders for the control of the flexibility assets made available by the end consumer;
1.2. a local interface that makes it easy for prosumers to determine the general response levels they want (i.e. determine their own comfort level);
1.3. a tool for estimating the benefit to the end consumer, which end consumers may access according to their consumption profile, appliances and required comfort level.

WP 2: Smart price signals:

Dynamic price generation is based on machine-learning algorithms that are able to use system conditions (imbalance, solar wind, congestion, day of the week…) as a way of learning which price level or price curve should be transmitted to consumers to elicit the desired response (smart pricing). Smart-pricing algorithms will initially be developed in the context of a community that consumes the power it generates, and will then be expanded to a broad range of use cases (general balancing, congestion management, local balancing, BRP portfolio balancing). Finally, the generated prices will be combined in the best possible way, specifically by incorporating the various components of grid tariffs. Among other things, the project will look at ways of managing the potential effects of overenthusiasm among consumers.

The ultimate aim is to develop two modular algorithm suites for use by the various stakeholders in the system (e.g. TSOs, DSOs, BRPs, local community managers):

- the first algorithm suite will set out to provide TSOs, DSOs, BRPs and so on with forecasting tools for predicting the flexibility they will need to resolve a situation (e.g. balancing, congestion);

- the second suite will aim to translate these flexibility needs into price signals. The price signals will then be aggregated so that consumers will only see a single price signal that reflects all the constraints. Given the innovative character of these mechanisms vis-à-vis the current market design, this part of the project will include a study examining the market mechanisms to be implemented and their regulatory implications, with a view to encouraging the integration of these new technologies.

WP 3: Ex-post settlement:

This part involves developing a secure, privacy-friendly transaction recording system that generates a falsification-proof log of events occurring over time, such as the fact that a given market player sent out a particular price signal, resulting in a given change in consumption at a particular location. The aim is to develop cryptographic algorithms that can collect and aggregate individual pieces of data (e.g. adding up the consumption of everybody in a neighbourhood) while also providing evidence that data were aggregated correctly. The algorithms will be integrated into a secure architecture, where the data are stored on a blockchain so that they can be checked by the relevant stakeholders. The result will be a software proof of concept, plus an estimate of the required computing power and an idea of the components to be integrated into the electricity grid's infrastructure.

WP 4: Societal impact and user engagement

Beyond the project's technical feasibility, the aim is to gain a better insight into the availability of flexibility. Tools will be developed with a view to identifying the flexibility already available from users, understanding how they behave towards this new approach to energy and determining the best way of getting them involved in the concept of smart, dynamic pricing.

The pilot project will also include a societal dimension aimed at understanding the perceptions of typical users, ranging from those from privileged socio-economic backgrounds to those affected by fuel poverty. This is essential, as it will allow an assessment to be made of the resources required to ensure that all end consumers (and not just privileged members of society) take full ownership of the solution. Participants can be recruited from the ORES customers who worked with the University of Mons (UMONS) on a smart-meter implementation project, i.e. 301 households from a social housing estate in Saint-Ghislain (Tertre)12. Of these 301 households, at least 141 have electric boilers. The target group has been identified and its members already have smart meters – there are at least 141 customers with boilers. This group has already responded positively to UMONS enquiries about other work. On this basis, the consortium is confident it will be able to put together a sample of 30 participants from this group.

WP 5: Pilot project

The pilot project aims to run a full test of the tools developed for the rest of the project. This will involve checking that customers receive the price signals, seeing how they respond and determining how appropriate their response is in light of the intended effect of the price signal. The pilot project will involve recruiting customers who have smart appliances, are connected to the ORES system and have had smart nodes installed. Multiple constraints must be taken into account; consequently, around one hundred customers need to be recruited for the pilot project, as set out in section 2.2.4 of the file.

Planning by work package

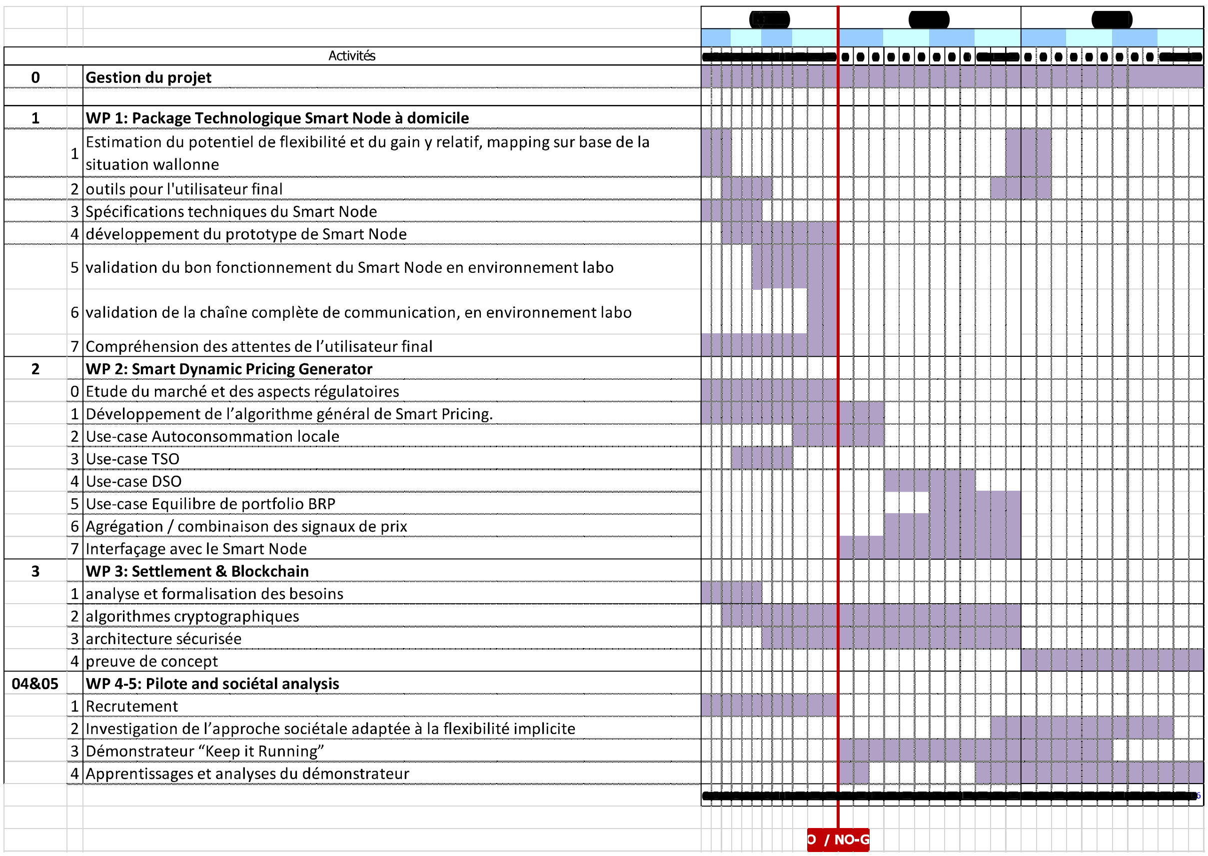


Figure 72 [redacted]

C. Context/stakeholders in the project

In this project, the consortium consists of:

- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]

The project aims to develop a range of tools to address the issue of how best to capitalise on flexibility, especially residential flexibility. It does not set out to develop a single product targeting just one type of player (e.g. grid operators, consumers or the management of systems for the consumption of self-generated energy) and while it may only resolve a small part of the problem, it may provide a solution addressing the entire issue through its various sub-projects and tools.

This is why the consortium was put together to address all the target players: potential managers of systems for the consumption of self-generated energy, BRPs, DSOs, TSOs, suppliers and end customers. The consortium's makeup means that it blends capacity for technical and algorithmic innovation, business experience, market knowledge and a customer portfolio that will allow the tools developed in the project to be tested in a real-life environment, with the partners' work on smart nodes, smart pricing, response and settlement, feeding into a comprehensive pilot project.

Here is a brief summary of each consortium partner's contribution to the individual parts of the project.

1. **Home technologies:** Laborelec will act as the technology lead in developing the smart node, ensuring it works properly and guaranteeing that it can be installed in end consumers' homes to control their flexible assets.

2. **Smart price signals:** Elia will act as the technology lead for this part of the project. [redacted] will contribute its knowledge of algorithms (Artificial Intelligence, machine learning, big data) and its experience of developing industrial solutions. The partners who may generate price signals for a specific use case (e.g. balancing, general and local congestion, BRP portfolio balancing) will be involved in jointly developing

smart-pricing algorithms. Elia will work on use cases related to the issues facing TSOs, ORES on DSO-related use cases, and [redacted] on use cases connected with the activities of BRPs and managers of community schemes for sharing self-generated power. [redacted] will contribute both the data required to develop the algorithms and the business experience that will make it possible to use the data more easily and interpret the results.

3. **Ex-post settlement.** UCLouvain will handle the technological aspects, drawing on its academic experience to provide the consortium with the latest state-of-the-art advances in cryptography and blockchain technology. [redacted] will be responsible for integrating these technologies while taking account of the operational constraints (e.g. smart meters at home), while [redacted] and Elia will integrate them into other developments.

4. **Societal impact and user engagement:** Finally, UMONS will examine the psychosocial issues associated with the project's rollout to customers, as well as the factors determining the use of customers' flexibility.

5. **Pilot project**: Laborelec will take the lead on managing the demonstrator pilot project. While [redacted] will coordinate recruitment, all the consortium partners will undertake recruitment activities to maximise the chance of success (participants will mainly be recruited from [redacted] customer portfolio, but there are also opportunities to recruit from specific areas through [redacted] the consortium partners' employees are another potential source of participants). Laborelec will contribute to the pilot project with its experience in implementing demonstrator projects (gained through other similar projects financed by public bodies or in-house) and its testing resources (laboratory testing or mobile equipment for on-site testing), as well as over 10 years' experience of energy flexibility in the residential segment. [redacted] and [redacted] to adjust the tools developed at earlier stages in the project based on their behaviour during testing.

D. *Value development plan*

How the project contributes to the strategic objectives

This project plans to develop a set of tools to tackle this problem and provide a solution to grid operators using the new flexibility that is available essentially at the residential consumer side.

Since one of the hypothesis to be tested is the opportunity to reduce the reservation and re-dispatching costs thanks to the liquidity increase of the flexibility product, the project is strongly contributing to improve the efficiency of Elia and the cost impact on the society.

Since the objective of the project is to test the implicit market mechanism (which does not yet exist in Belgium), the project is strongly contributing to improve the market concept.

Link with Elia's other innovation objectives

The project will focus on making the markets evolve towards a more consumer-centric model to maximise the amount of flexibility available for the market and therefore minimise the cost of grid balancing for the society.
It also reinforces Elia's position as a front-runner.

Implementation plan

No implementation plan is ready yet as this project is purely an explorative innovation. For the moment the plan is to test via a pre-consortium the technical feasibility of such a mechanism in laboratory conditions. More information about the consortium, which is called CheckMyFlex, can be found here:
https://innovation.eliagroup.eu/projects/ioenergy-checkmyflex/

Potential next steps

The potential next steps are to implement the implicit mechanism in a new consumer centric market design and successfully use the residential flexibility to support the TSO business.