

USAGE OF DRONES

(SDC WG Asset Implementation and Management - Work Stream 1 Technologies)
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ENTSO-E Mission Statement

Who we are

ENTSO-E, the European Network of Transmission System Operators for Electricity, is the association for the cooperation of the European transmission system operators (TSOs). The 39 member TSOs, representing 35 countries, are responsible for the secure and coordinated operation of Europe's electricity system, the largest interconnected electrical grid in the world. In addition to its core, historical role in technical cooperation, ENTSO-E is also the common voice of TSOs.

ENTSO-E brings together the unique expertise of TSOs for the benefit of European citizens by keeping the lights on, enabling the energy transition, and promoting the completion and optimal functioning of the internal electricity market, including via the fulfilment of the mandates given to ENTSO-E based on EU legislation.

Our mission

ENTSO-E and its members, as the European TSO community, fulfil a common mission: Ensuring the security of the inter-connected power system in all time frames at pan-European level and the optimal functioning and development of the European interconnected electricity markets, while enabling the integration of electricity generated from renewable energy sources and of emerging technologies.

Our vision

ENTSO-E plays a central role in enabling Europe to become the first climate-neutral continent by 2050 by creating a system that is secure, sustainable and affordable, and that integrates the expected amount of renewable energy, thereby offering an essential contribution to the European Green Deal. This endeavour requires sector integration and close cooperation among all actors.

Europe is moving towards a sustainable, digitalised, integrated and electrified energy system with a combination of centralised and distributed resources. ENTSO-E acts to ensure that this energy system keeps consumers at its centre and is operated and developed with climate objectives and social welfare in mind.

ENTSO-E is committed to use its unique expertise and system-wide view – supported by a responsibility to maintain the system's security – to deliver a comprehensive roadmap of how a climate-neutral Europe looks.

Our values

ENTSO-E acts in solidarity as a community of TSOs united by a shared responsibility.

As the professional association of independent and neutral regulated entities acting under a clear legal mandate, ENTSO-E serves the interests of society by optimising social welfare in its dimensions of safety, economy, environment, and performance.

ENTSO-E is committed to working with the highest technical rigour as well as developing sustainable and innovative responses to prepare for the future and overcoming the challenges of keeping the power system secure in a climate-neutral Europe. In all its activities, ENTSO-E acts with transparency and in a trustworthy dialogue with legislative and regulatory decision makers and stakeholders.

Our contributions

ENTSO-E supports the cooperation among its members at European and regional levels. Over the past decades, TSOs have undertaken initiatives to increase their cooperation in network planning, operation and market integration, thereby successfully contributing to meeting EU climate and energy targets.

To carry out its legally mandated tasks, ENTSO-E's key responsibilities include the following:

- › Development and implementation of standards, network codes, platforms and tools to ensure secure system and market operation as well as integration of renewable energy;
- › Assessment of the adequacy of the system in different timeframes;
- › Coordination of the planning and development of infrastructures at the European level (Ten-Year Network Development Plans, TYNDPs);
- › Coordination of research, development and innovation activities of TSOs;
- › Development of platforms to enable the transparent sharing of data with market participants.

ENTSO-E supports its members in the implementation and monitoring of the agreed common rules.

ENTSO-E is the common voice of European TSOs and provides expert contributions and a constructive view to energy debates to support policymakers in making informed decisions.

TABLE OF CONTENTS

EXECUTIVE SUMMARY	4
1 Introduction	5
2 Background and Motivation	5
3 Results of the survey related with the current usage of drones	6
4 Burdens and needed improvements for a widespread usage of drones from TSOs point of view	10
5 Use Cases of TSOs regarding drones	11
6 Workshop “New asset management approaches using drones”	12
7 Next Steps	13
8 Closer insights into best practices	13
Glossary	16
Annex	18
References	16

EXECUTIVE SUMMARY

The aim of this report is to give ENTSO-E members the information they need to make decisions on the introduction or further development of the use of drones in their grid. Based on a survey conducted under ENTSO-E members the following results can be stated:

- All 23 questioned Transmission System Operators (TSOs) have experiences with drones, but as of today the use of drones is not broadly integrated in daily work processes and often used on an experimental level.
- 65% of TSOs currently own drones, however many TSOs (70%) also use external contractors for drone activities.
- As of today drone use seems to focus on camera inspections of the tower and wires.
- 70% of TSOs do not use drone technology for daily activities, which can partly be linked to legal limitations. More than half of the questioned TSOs also stated that regular Beyond Visual Line of Sight (BVLOS) flights are prohibited by their country regulations.
- Most TSOs expect that drones will be widely used in the future and will help to increase efficiency in maintenance, but also security of supply.

1 Introduction

This report gives a summary of a survey conducted under ENTSO-E members. The aim of this report is to give ENTSO-E members an overview of the current use of drones at TSOs and to provide the information they need to make decisions related to the use of drones in their grid.

Considering the fact that drone technology is advancing rapidly, it is planned that this report will be reviewed approximately two years after final publication.

2 Background and Motivation

Power grid inspection and asset management are an integral part of power grid maintenance. Modern technologies like drones offer many new possibilities and should be used with the goal to improve quality and productivity of the power grid maintenance, which will ultimately support reliability, security of supply and cost-effectiveness. Various ENTSO-E members are currently working on test runs, pilot projects and research activities related to the use of drones. Even though the areas of application are very broad, this report aims to give an overview of potential usages of drone technology.

Drones themselves have made great progresses and astonishing developments in recent years. Today they are much smaller, more efficient (in terms of range or flight time) and cheaper than ever before, and current developments are expected to bring further improvements in the next years.

The use of drones is often closely connected to other emerging technologies such as new or improved sensor technologies (LIDAR, VIDAR), autonomous flight systems, big data management and edge computing or image recognition using artificial intelligence (AI). It is foreseeable that these technologies will play a larger role in future maintenance strategies and will allow improved predictive maintenance mythologies.

In the context of transmission systems and use cases for TSOs, limits of the usage of drones are often also connected to regulatory aspects and legal questions related to flight permissions.

Since technology developments in these fields are very dynamic, existing use cases for drones for TSOs will become more common in the next years and new use cases will emerge.

The focus of the questionnaire was therefore:

- to collect information about the current usage of drones among ENTSO-E members,
- to give an overview of ongoing R&D activities by TSOs,
- to identify necessary further developments to meet the needs of TSOs, and
- to provide examples of best-practices and available use cases related to the usage of drones

The questionnaire was therefore divided into several sections and asked about the use and experiences as well as expected further developments and prospects as well as further needs on the drone market. The questionnaire was sent via SDC to all ENTSO-E members in 2019 and answers from 23 TSOs were collected.

3 Results of the survey related with the current usage of drones

All 23 questioned TSOs have experience with drones, at least on an experimental level. 65% of TSOs currently own drones, however 70% of TSOs also use external contractors for drone activities. 70% of TSOs answered that at the moment the use of drones is not broadly integrated in daily work processes, but rather experimental.

Drones are in regular use or used in pilot projects in special use cases, were most of them are connected to inspection and vegetation management, but also support construction works (including planning processes)—some examples are:

- RTE: pilot project for vegetation management (use of Lidar, R&D activities)
- APG: usage for inspections in case of bad accessibility; provide image database to find optimal route new lines
- Statnet: mounting of bird and aviation markers
- REE: usage for inspection planned; pilot test for stringing new line in protected environment
- Terna: support maintenance with images of power lines
- Amprion: pilot project for inspection of overhead lines and hotspot-analysis

The main motivations for TSOs to promote the use of drones are:

- Higher efficiency
- Improved planning processes for maintenance
- Reduced repair time in emergency situations
- Good publicity / shows innovation to stakeholders

Identified advantages and fields of application

In the last decades power grid inspections have been mainly done manually by power line engineers. This process often requires laborious work and sometimes power transmission interruptions. The recent introduction of drones in power system inspection brings several advantages to the power industry:

- Increase safety and decrease risks to maintenance technicians
- Decrease maintenance equipment downtime
- Enhance accuracy in data collection of an asset's condition

- Reduce staffing need and associated employment cost
- Repurpose maintenance inspection of truck rolls for other uses

Technology Types in use

Currently piloted drones also have the potential to fly automatically or autonomously via GPS self-positioning. However concerns related to the accuracy of GPS systems in close vicinity to high voltage lines (electromagnetic interferences, disturbed satellite signals by towers) and possible drone flight errors were mentioned. Self-position estimations via image processing could solve this issue when the GPS is not available.

The following types of technologies are used today:

- Piloted drones (Unmanned aerial vehicles (UAVs))
- Automatically flying drones
- Autonomously flying drones (mostly used for test flights so far)

Components & enablers

BVLOS flights can be seen as a stepping stone towards a wider use as well as empowering nowadays' uses. Currently many activities concentrate on experimental BVLOS flights: All asked TSOs answered that they have already used drones. 70% of TSOs focus on experimental flights and about 43% have already performed at least one BVLOS flight.

Legal frameworks differ among the participating TSOs, however regulations regarding BVLOS flights are changing rapidly. 70% of TSOs answered that experimental BVLOS flights are allowed under current law (Figure 1), whereas in 52% of participating countries regular BVLOS flights are still restricted (Figure 2).

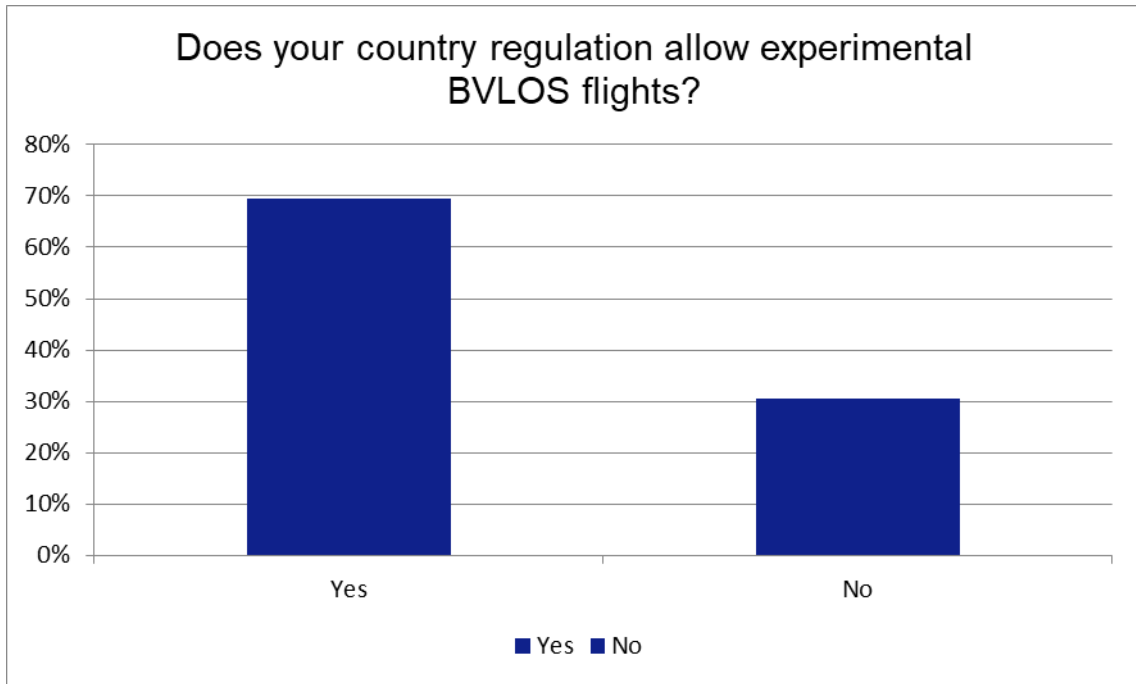


Figure 1 Answer to question: Does your country regulation allow experimental BVLOS flights? (23 answers received)

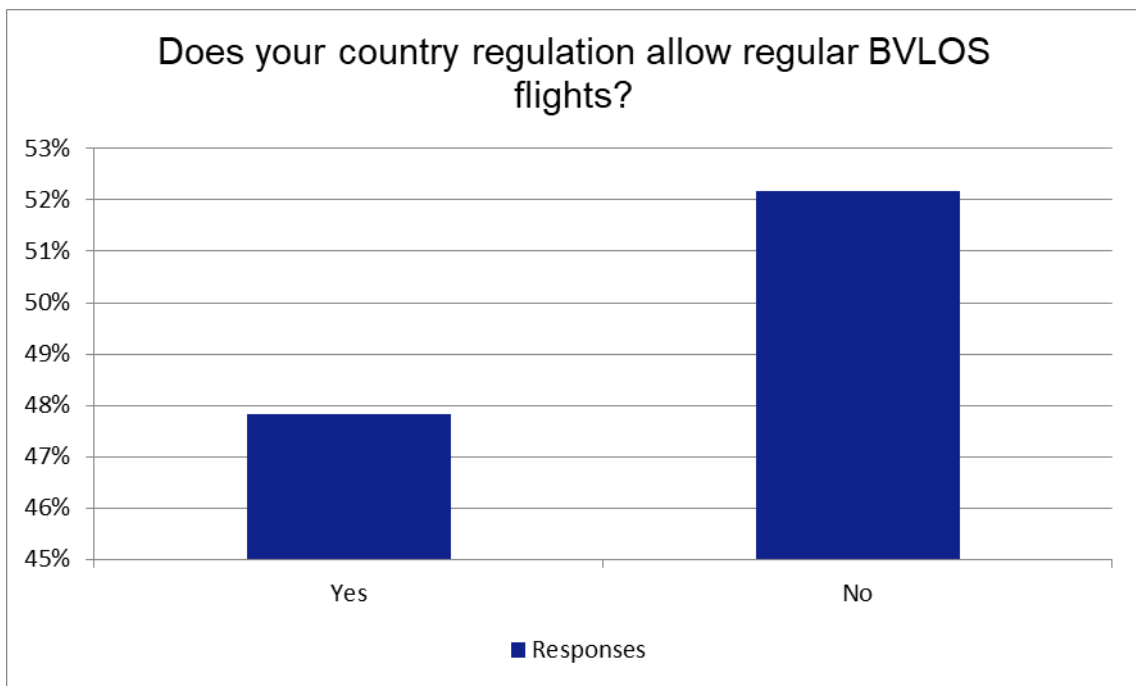


Figure 2 Answer to question: Does your country regulation allow regular BVLOS flights? (23 answers received)

Only 34% of TSOs have already performed an autonomous flight (Figure 3).

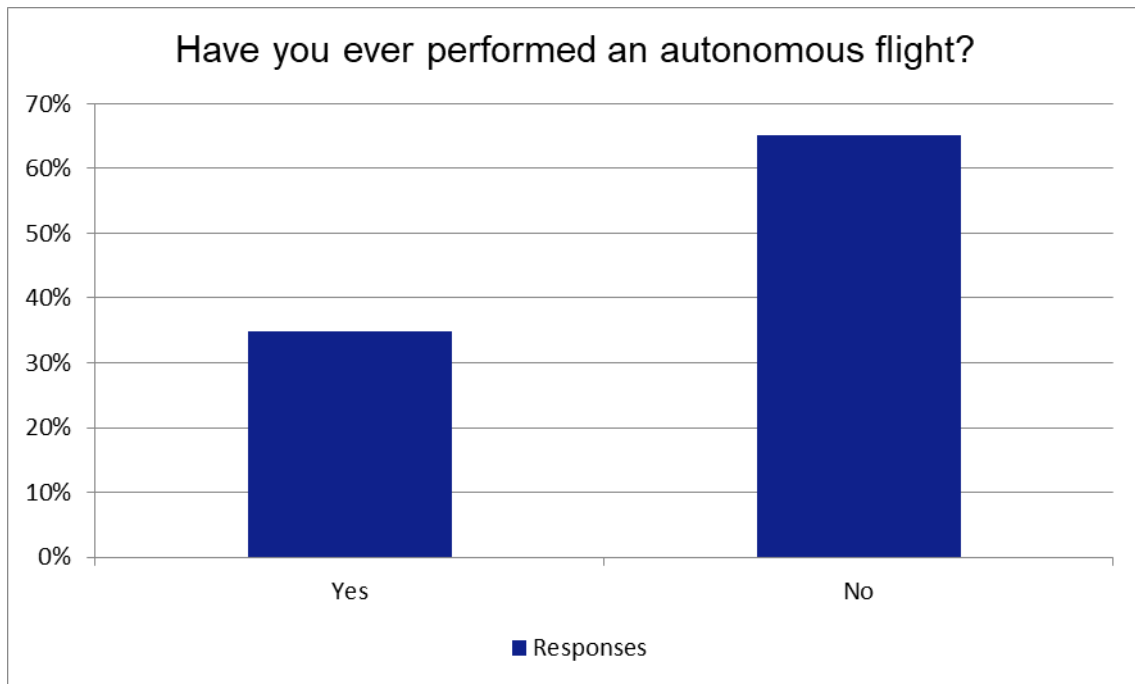


Figure 3 Answer to question: Have you ever performed an autonomous flight? (23 answers received)

However the results clearly show the strong interest of TSOs in further research, 57% of them answered, that they are investing resources into drone research.

The following enablers were specifically mentioned:

- Self-positioning (GPS, image processing and other sensors for navigation)
- Unmanned Traffic Management (UTM)
- Sensors for condition detection of vegetation, OHL components (e.g. steel corrosion) and other topics, by using and gathering visual, thermal, UV and audible information

4 Burdens and needed improvements for a widespread usage of drones from TSOs point of view

The results of the questionnaire show that there exists a need for improvements. For example, if there were no limits in battery duration, payload or regulation (permission), most TSOs would use drones for monitoring and inspection, mainly in OHL, but also in substations, as well as for fault locations and support of construction works.

The following fields of needed improvements were identified in the survey:

- Extended flight times and flight ranges
- Autonomous navigation and out of sight flight
- Higher possible loads / weights to mount different types sensors
- Noise of drones and need of silent operation for frequent flights along transmission lines.
- Improved sensors (speed, accuracy, ...)
- Reduced costs
- Improved mobile CPU power
- Better software (better AI analyses) in all use cases
- Improved data management technologies
- Cloud solutions
- Regulation and legal questions
- Clear legal framework regarding flight permissions and flight restrictions for third parties
- Legal framework in the context of data protection

Most TSOs expect that drones will be widely used in the future and mentioned in this context:

- Condition assessment, based on photo or video analyses and AI, that could predict future need for maintenance (predictive maintenance) and fault prevention
- Small maintenance actions, e.g. installation of markers on conductors, delivery of spare parts and other action without the need of a high payload

5 Use Cases of TSOs regarding drones

Regarding the use cases, TSOs responded as shown in Figure 4.

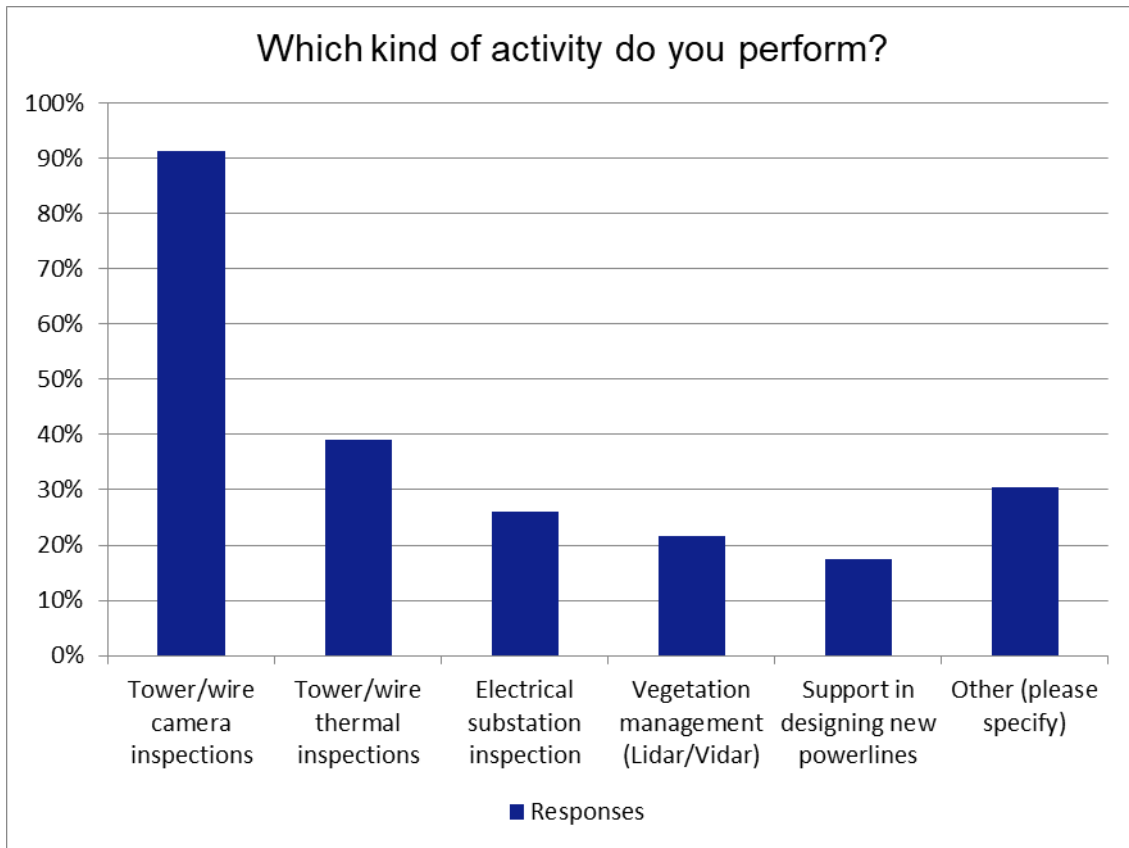


Figure 4 Answer to question: Which kind of activity do you perform? (23 answers received)

The most common use cases in use or from high interest in the short term are:

- BVLOS and autonomous flights on a regular basis to monitor the right of way (vegetation, conditions of different parts, (natural) hazards)
- Inspection after faults including fault detection
- Possible use cases of TSOs regarding drones (wish list of TSOs, challenge the industry)
- Impact of drones on TSOs
- Future: Terna plans to use its own drones in the future; use for inspections of power line and maybe also for inspection of substations

TSOs reported the following wishes to improve the results of use cases:

- Vegetation management: faster management and data processing, checking of results to ensure less vegetation related faults
- Change management: identification of hazards earlier to have the possibility to take preventive actions and to increase the security of supply
- Rout of way management: identification of hazards more accurately
- Mount bird and air markers: developed technology for regular use to reduce the need of shut downs and therefore to increase security of supply

6 Workshop “New asset management approaches using drones”

To discuss the results of this document a workshop was held on the 29th of June 2021, the agenda is attached to the document as well as detailed information on discussions. Due to the current pandemic, the workshop was held online and Slido was used as an interactive tool to promote discussions. All in all up to to 45 participants who were also actively involved and asked 29 questions.

At the Workshop six expert gave their input regarding the status of drone usage in Europe. Two TSOs (APG and 50Hertz) presented their experiences and research projects. Two other industries (Rijkswaterstaat - Ministry of Infrastructure and Water Management of the Netherlands and a Subsidiary of SNCF Réseau) presented how they use drones to detect corrosion on railways and bridges. EASA and UAV Dach explained the newly introduced legislature regarding drones and shared their tips on how to navigate possible bureaucracy.

The words in Figure 5 popped up the most throughout the workshop:

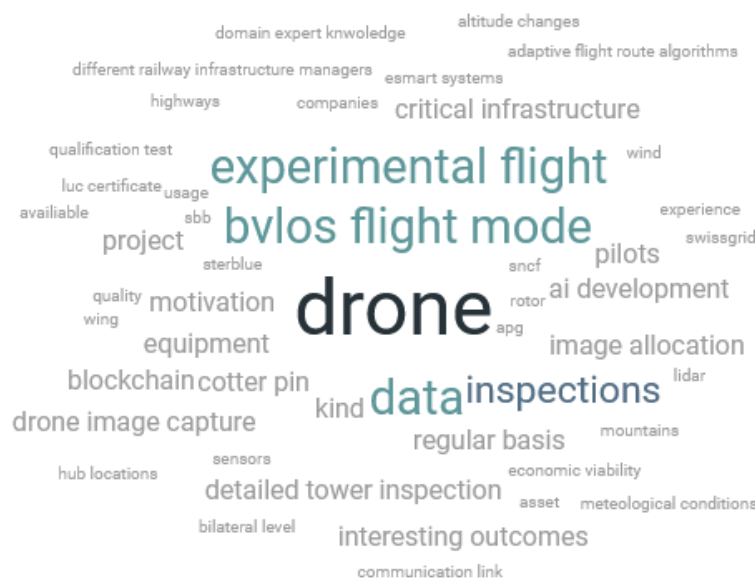


Figure 5 Snapshot of Slido showcasing the most typed words of the workshop

After each presentation attendees were able to ask question. The workshop concluded with a 30 minutes long discussion regarding future steps.

The following learnings came out of the workshop:

- Regulatory limitations are not the main problem but rather the knowledge about changes in regulations within the last years as well as in the future
- An ENTSO-E position paper was perceived positively
- Such an ENTSO-E position paper should focus on
 - joined AI Research
 - data sharing
 - developing a standard scenario for drone flight to simplify regulatory issues

7 Next Steps

Following the results of the questionnaire as well as the workshop the next steps will focus on regulatory issues. In order to help TSO in regulatory issues a guide is planned to be shared (under evaluation).

In further steps it will also be decided if TSOs are interested in the joint effort of a position paper and which regulator issues the position paper should focus on.

Data sharing and joined AI Research could provide future working fields however will not be included in the immediate next steps as it would go beyond the scope of the report.

8 Closer insights into best practices

RTE/ France

RTE has launched several experiments with drones: a drone within a substation or a drone around a tower operated by a RTE crewman with live video or picture camera for diagnostic maintenance, drone pulling about cable to initiate the leverage of the main aerial cable, long distance drone flights (over 50 km) remotely operated to survey a 400 kV line.

- Design

The long distance drone weights 2 kg, has a 50 km 50 minutes range flight at 150m height at 50 km/h speed.

Recently RTE carried out a successfully tested a BVLOS automatic flight with an UAV airship carrying a payload of around 10kg for photographic inspection of conductors and pylons.

- Result

Since 2016, RTE is an official aeronautic drone operator. Drones simplify maintenance diagnostic in live line conditions. It gives flexible alternative to helicopters in some specific use case. 500 line crewmen will be trained to be fully operational in 2021.

Recently RTE carried out a successfully tested a BVLOS automatic flight with an UAV airship carrying a payload of around 10kg for photographic inspection of conductors and pylons.

APG/ Austria

The technical evaluation of assets as well as maintenance is very important for APG. Drones are used to assess the distance of conductors to vegetation. Another area of application is the identification of the asset status for the planning process of new transmission lines.

- Design

Already in use are 360° videos and pictures recorded by drones.

- Result

360° videos and pictures are helpful for a quick check of the situation on-site without the need to physically go there. The 360° perspective has the advantage to have a higher possibility to have objects of interest recorded, even if the route of line was not yet fixed at recording time. Furthermore Virtual-Reality-animations are used to give residents an idea, what a project will look like.

CEPS/ Czech Republic

CEPS, together with its technical partner, developed its own type of drone in 2014. The drones can be equipped with RGB or a thermal camera and are operated by CEPS crewmen. The drones are mostly used for ad-hoc power line inspections in case of a successful or unsuccessful reclosing and to control quality of repairs both with thermal and RGB camera. The drones are also used in case a helicopter cannot conduct an inspection for a specific part of a power line.

- Design

Custom made drones flying VLOS reaching the end of their lifetime. The drones will be replaced with DJI Mavic 2 Enterprise and DJI Matrice 300 RTK drones during 2021.

- Result

CEPS has over 5 years of experience with their custom-made drones helping with inspections after power line reclosing, repairs or in case of missing helicopter control. During 2021 CEPS plans to acquire new DJI drones and to have 6 licensed pilots to fly them.

TenneT/ Netherlands

For the condition evaluation of the high voltage lines, TenneT in the Netherlands uses two forms of inspections namely, general line inspections by walking along the lines and detailed tower inspections, by climbing the towers. We have recently completed trials with a few drone companies to gather very high resolution images of insulator strings, in these images we were able to distinguish tiny features like cotter pins. The main difficulty was keeping the drone camera on focus while maintaining a safe distance of > 10 from the tower and conductors.

- Design

For this trials, the best images were obtained using a PhaseOne iXM 100 camera with a 150mm lens mounted on a DJI M600 pro drone.

- Result

These images can be greatly helpful in assisting remote inspections and eventually a combination of human and AI for detecting defects and anomalies. The next steps are to have a fine tuned flight system to be able to auto capture images with the right focus and detail. The biggest challenge is the unavailability of a training dataset to train AI models for anomaly detection.

Terna/ Italy

In the last couple of years drones have been used in Terna to monitor the condition of towers and conductors. With the current national regulation, this operation can be done only in visual line of sight.

In the end of 2019 Terna has launched a BVLOS experimentation, together with the national flight authority, in order to extend the range of the inspection and increase its efficiency.

- Design

A multirotor drone, equipped with camera and IR camera, with a 45-minute range flight has been used for the test.

- Result

The inspections of towers and catenaries has been conducted for a 3 km range of powerline thanks to the BVLOS flight test. Detailed images of tower components, such as insulators, have been taken and were really useful to monitor the status of the line, as well as the IR video that has been recorded on the conductors to detect hotspot. Compared with traditional methods of inspection, drones can be considered a useful tool for asset management workers.

A second test will be done in 2021 with a fixed-wings drone equipped with Lidar on a 20 km powerline.

References

- [1] S. Sato and T. Anezaki, "Autonomous flight drone for infrastructure (transmission line) inspection (2)," 2017 International Conference on Intelligent Informatics and Biomedical Sciences (ICIIBMS), Okinawa, 2017, pp. 294-296.
[Link](<https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8279697>)
- [2] Elia group innovation. Drones today and future development.
[Link](<http://innovation.elia.be/asset-management/drones-today-and-future-development/>)

Comments to this report or do you want to tell us more about your use case or perspective?
Please contact klemens.reich@apg.at (WG AIM/ WS1)

Glossary

AI	Artificial Intelligence
AIM	Asset Implementation and Management
APG	Austrian Power Grid
BVLOS	Beyond Visual Line of Sight
ČEPS	Česká energetická přenosová soustava, a.s.
CPU	Central Processing Unit
EASA	European Union Aviation Safety Agency
ENTSO-E	European Network of Transmission System Operators for Electricity
GPS	Global Positioning System
IR	Infrared
LIDAR	Light Detection and Ranging
OHL	Overhead Line
REE	Red Eléctrica de España
R&D	Research & Development
RGB	Red, Green, Blue
RTE	Réseau de Transport d'Électricité
SDC	System Development Committee
TSO	Transmission System Operator
VIDAR	Visual Detection and Ranging
UAV	Unmanned Aerial Vehicle
UTM	Unmanned Traffic Management
UV	Ultraviolet
VLOS	Visual Line of Sight
WG	Working Group

Annex

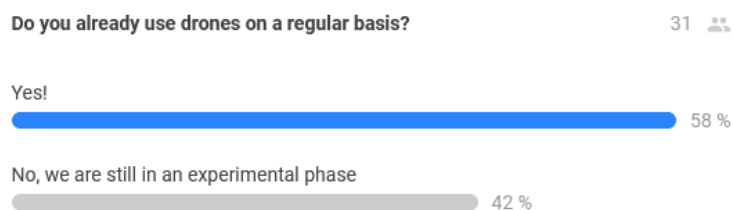
Agenda of the Workshop “New asset management approaches using drones”

The workshop was held on the 29th of June 2021

No	Subject	Presenter	Time	Mode
1.	Welcome and Introduction Agenda of the day	Jorge Valero Ortega	09h00-09h30	Introduction
ENTSOE - TSO Drones Report				
2.	Main findings of the Report “Usage of Drones”	Jorge Valero Ortega	09h30-10h00	Keynote
3.	50Hertz Transmission: service experience with autonomous flights	Arya Fazilat	10h00-10h30	Presentation Q&A
4.	15 minutes e-coffee break		10h30-10h45	
5.	Austrian Power Grid: service experience with autonomous flights	Rainer Wagenhofer	10h45-11h15	Presentation Q&A
Drones usage in neighbouring industries				
6.	Introduction of other industries facing the same issues	Klemens Reich	11h15-11h30	Introduction
7.	Altametris (Subsidiary of SNCF Réseau)	Anthony-Victor Mehl	11h30-12h00	Presentation
8.	Rijkswaterstaat (Ministry of Infrastructure and Water Management of the Netherlands)	Ariea Vermeulen	12h00-12h30	Presentation
9.	1h Lunch Break		12h30-13h30	
New EASA regulation for drones				
10.	Introduction of the topic of regulations	Klemens Reich	13h30-13h45	Introduction
11.	UAV DACH e.V. - Unmanned Aerial Vehicle Association	Paul Eschbach	13h45-14h15	Presentation
12.	European Union Aviation Safety Agency (EASA)	Natale Di Rubbo	14h15-14h45	Presentation
13.	15 minutes e-coffee break		14h45-15h00	
Discussions of barriers and future applications				
14.	Discussion	Klemens Reich	15h00-15h30	Open Discussion (online app)
15.	Wrap up and conclusions of the workshop	Klemens Reich	15h30-16h00	Wrap up

Interactions

The following interactions took place via Slido:



If yes, what is your main use case?

19 

we do extraordinary checks after succesfull or unsuccesfull switching OHL

corona listening!

We use small DJI drones after failure of equipment on high voltage lines. For LIDAR we use manned helicopters (regulations, payload issues). A fist line linspection (150 pylons and spans) is planned using drones and AI for data allocation and AI image treatment.

Mechanical inspection of the tower. Inspection of the conductor, press connector.

work preparation, tower detailed inspection for end of life optimization, diagnose incident, inspect critical spans that are not inspected by helicopter, transformer detailed inspection,

how ot handle the big data of the pictures taken, that is also something of our bussines case... data warehouse and the dashboard!

tower inspections, esp. after repair/renovation, also thermal

Corrosion detection on pylons and condition of the isolators. Lidar for line modelling and vegetation management.

Tower inspection

spacers check also

Inspection of towers and lines

Thermal inspections

inspection of assets (towers, substations, buildings) Surveys (documentation of infrastructures)

Visual inspection.

Check insualtors after reclosing.

tower inspection

vegetation checking, detailed tower inspections (insulators, pins, thermal things), checking painting renovations of towers

full stuff, but main essence is the cotter pin. E.g. rust is rather 'easy' to detect and to put in AI.


Quality assessment in maintenance projects (e.g. corrosion protection, insulation change, etc.) check for event-related messages (e.g. lightning strike) ecological construction supervision possible as part of maintenance measures Asset inspection (line technology and substation technology, and cables in the future)

Visual inspection.

Tower inspeccion.

Mostly during project handover.

inspection

According to your opinion, would it be helpful to have a common Entso-E position paper on drones regulation? If yes: Can you explain the benefits you see? Would you or your company would like to join a drafting team? 9 

Ranjan Bhuyan: joined AI Research would be interesting Arnold Trümpi (Swissgrid) wants to push data as a whole – not only the usage of drones Marius Oltean (Transelectrica) – focus on other uses of drones – installation etc instead of doing it with helicopters Martin Zagora (CEPS): it is difficult to capture data with helicopters. It is easy to come very close to the line (5m) so this is not an issue for CEPS. With drones the resolution of data can be a problem Ranjan Bhuyan (Tennet) Consistent Quality is the problem with drones Michiel Uwaerts (ELIA): Start a stream on robotics? – maybe to broad, robotics can be used in many different ways, so it should be more focused on one specific use case of robotics and not just the objective 'robotics'

yes, for sure this will help. not only for maintenance but also for improving the KPI on grid availability. TenneT would like to contribute.

Yes we would be interested

Yes it would, transmission operators need to push for more autonomy and freedom in imaging of their own assets without interference from other regulatory bodies as well as standardizing the information and data analysis so it's compatible with TYDP.

Yes, common approach to the process across the ENTSO. Lesson shared etc... EirGrid currently doesn't have much experience in the area of drones however it is sometime we are looking to for future improvements in asset management

Common position paper would be welcomed, as we are starting to use drones in more and more situations. Our main topic would be BVLOS but as new regulation is in effect only a small amount of time, it is hard to imagine its effect on our TSO. Sharing of data could be also very interesting. We have no problem with participation in drafting team.

Yes such a position paper is considered to be very helpful. One of the key topics should be the creation of a joint AI platform where we share asset related raw data for training purposes of ML algorithms. Swissgrid is willing to contribute to such a position paper, and use cases shall be in the center of such a position paper.

It will be very helpful. The regulatio is common for EU and ENTSO-E should have a common opinion. I think TRANSELECTRICA will join a drafting team.

If this could help setting the operational perimeters that TSO's will be using during the main operations, Absolutely. Getting this as a Standard scenario or PDRA