DISRUPTIVE SOLUTION TO MITIGATE RISK AND INCREASE EFFICIENCY IN EDP DISTRIBUIÇAO, OVERHEAD LINES INSPECTIONS

SOUSA, Paulo Alexandre
EDP Distribuição
(EDP Group), Portugal
pauloalexandre.sousa@edp.pt

SANTOS, Ricardo Jorge
EDP Distribuição
(EDP Group), Portugal
ricardojorge.santos@edp.pt

BERNARDO, Rui.
EDP Distribuição
(EDP Group), Portugal
rui.bernardo@edp.pt

ANDRÉ, Artur Matos
LABELEC
(EDP GROUP), Portugal
artur.andre@edp.pt

ABSTRACT

In order to manage the technical condition of its physical assets and according to its established asset management policy, EDP Distribuição frequently inspects its High Voltage (HV) and Medium Voltage (MV) overhead power lines. Such inspections are carried out by a specialized service provider, using a manned helicopter or personnel on the ground. Helicopter inspections require a crew of at least an experienced pilot and two technicians are expensive and have security concerns (risk of mechanical failure or collision).

Unmanned Aerial Vehicles (UAV) bring potential benefits, since they partially mix the advantages of having a fast, potentially economic and autonomous scanning of a predefined set of waypoints with the flexibility of having closer looks at specific points on the grid and with a significantly lower operational risk.

Furthermore, current inspections methods, like thermographic analysis and Light Detection And Ranging (LiDAR), are giving growing amounts of information which have to be properly managed using adequate algorithms. In this context, EDP Distribuição promoted the development of an algorithm to support the decision making process, regarding interventions on detected anomalies and subsequent works based on several relevant criteria, and is performing field tests with some commercial UAV solutions.

INTRODUCTION

Manned Air Inspections (MAI)

EDP Distribuição, (EDP Group) is the Portuguese Distribution system operator (DSO), managing about 80 thousand kilometers of HV/MV overhead lines. The company has been performing helicopter inspections of overhead electric transmission and distribution lines since 1995, through one of the other EDP group companies, LABELEC, with tangible benefits for its maintenance programs. These inspections include an Infra Red (IR) camera, a Daylight TV camera and, recently, an Ultra Violet (UV) camera (for daylight corona detection) and a Digital Single-Lens Reflex (DSLR) camera for quality digital photos, all contained in a high stabilization gimbal. A LiDAR system is also used, since 2008, for making measurements and geo-referencing abnormal distances between trees and other obstacles and the conductors. Visual inspections benefit from the use of stabilized binoculars. All these sensors may be present in the same helicopter, allowing for simultaneous multiple inspections in a single flight.

Figure 1 – Helicopters used by Labelec

Usually airborne inspections cover from 15.000 km to 25.000 km of power lines, with a helicopter operating all year and, when necessary, a second helicopter operating for half of the year.

Data Management:

In the case of visual and thermographic inspection, the generated data is thoroughly handled by EDP Distribuição specialized service provider (LABELEC), resulting in a organized set of detected anomalies with severity classification and GPS coordinates that almost don't require further processing.
On the other hand, the LiDAR method generates huge amounts of data, from distance measured to each individual obstacle, types of obstacles, GPS coordinates and handwritten notes amounting to several thousand data rows for each HV and MV overhead line, thus rendering human analysis virtually impossible.

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Figure 2 – Example of data from LiDAR inspection.

The necessity arose to develop a method to process this data, grouping similar nearby obstacles to a single resolution intervention (e.g. vegetation management or heightening lines over buildings), giving precise geographic directions for the fieldwork teams, and budgeting/optimizing the interventions based on the following criteria:

- Distance to obstacles (trees, ground, buildings, etc)
- Geographic localization of anomalies
- Type of underlying vegetation and respective growth rate
- Type of intervention (pruning, cutting, etc) and respective costs

UAV

The currently available UAV that are being used for power line inspections can be divided in two main types: helicopter and fixed wing (plane). Helicopters are slower but their flexibility helps one to keep standing in a fixed position in the air and to get a closer look of an area or equipment. Among helicopter type, one can find the single main rotor helicopter and the quadcopter. The generic single main rotor helicopter type works with a gas-fired rotor and is heavier than a quadcopter. It's harder to control, thus requiring an experimented pilot and more restrict safety concerns. The quadcopter is composed by more than two rotors (typically four), allowing for smaller configurations and making it easier to control (for most cases one or two days of training is enough to start a safe flight).

METHODOLOGY

MAI

The MAI crew includes a pilot, an IR inspector and a visual inspector that also helps the pilot detecting obstacles in the flight path. The IR inspector uses a monitor with IR images and TV images as the helicopter flies at a distance varying from 15 m to 30 m to the conductors. Every hotspot detected is digitally frozen, quickly analyzed and the thermal image is saved for further analysis and processing in office. Hotspots occur at a rate of approximately 2 km per 100km.

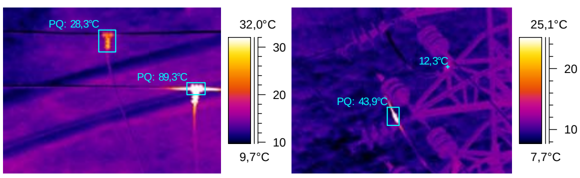

Figure 3 – Detected hotspots.

The visual inspector detects and takes notes of every visual fault observed on the line, using stabilized binoculars to help analyze faults whenever necessary. He also helps the pilot in detecting obstacles in the helicopter path. Visual faults, as well as IR faults, are geo-referenced and may be photographed using the DSLR camera.

Figure 4 – Broken insulator; broken ground wire

The track clearance (LiDAR) inspection requires only occasional supervision of the MAI inspectors in order to make sure that the laser scans cover the area of interest along the power line. The LiDAR system accuracy (laser scanner range error < 0,2 m, effective range up to 50 m, for MV lines, or up to 100 m, for Very High Voltage lines) combined with the GPS accuracy (error < 1 m) and the automatic analysis (supported by operator intervention and corrections) of the LiDAR data in office provide a voltage dependent three level code for clearances thresholds around each conductor, that allows the production of useful outputs for vegetation management purposes.

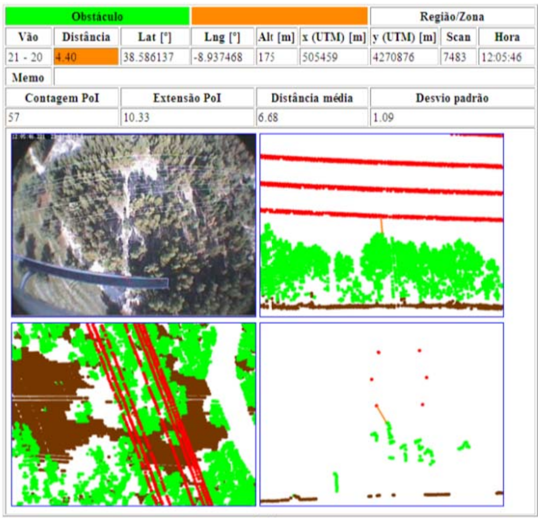

Figure 5 – LiDAR inspection – serious abnormal distances detected.

Daylight corona detection, using a UV camera, allows the detection of corona activity originated by dirty (due to coastal salt, industrial vapors and dusts, cement dust, among others), damaged insulators (cracked porcelain insulators, rusted cement metal caps on porcelain insulators, damaged composite insulators) or damaged conductors. Some of these faults are very difficult or even impossible to detect visually. Only a UV camera alert will allow suspecting of their existence.

Figure 6 – UV inspections - damaged ceramic insulator

DATA MANAGEMENT ALGORITHM

This tool works in a predefined sequence of steps, starting with the calculation of distances between consecutive anomalies, using the Haversine equation. The points are then grouped to form individual interventions regarding their relative distances and type of obstacles (trees, buildings, etc), while simultaneously calculating an estimate of the amounts involved in their resolution.
The focus is maintained in surgically correcting the most severe type of anomalies, represented in red in Figure 5, and a band of 100 m before and after them. The remaining anomalies are stored in databases, and depending on the vegetation species present below the lines and their growth rates, automatic alerts are generated, in the following years, in order to lead the service providers to the required spots.

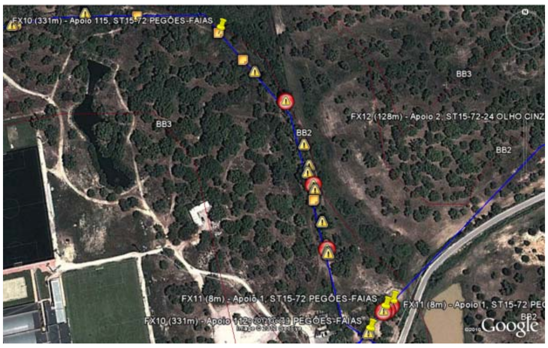

Figure 7 – Lines, anomalies, interventions and vegetation types on Google Earth

All service orders delivered to the service providers contain georeferenced (line name and pole numbers) interventions with cost estimate and expected time schedule. Georeferencing the anomaly is obtained through a careful analysis of the overhead lines and poles databases using a divide and conquer algorithm that searches the nearest points to a given intervention. Georeferencing goes one step further by uploading the HV/MV grid and intervention spots (yellow pins in) into Google Earth, thus allowing a easy and quick way to share all the information between the agents involved in this process. While the main focus of this process is vegetation management, several other anomalies are detected and solved, like proximity to buildings and intersections with other lines. In this case of "static" anomalies, a database is being built in order to prevent recurrent displacement of specialized workers to inspect the anomalies in future inspections.

UAV @ EDP DISTRIBUIÇÃO

EDP Distribuição has been participating in test flights with UAV for power line inspections, with helicopter type UAV (AIRTICI project) and with two different quadcopter type UAV solutions (from UAVISION and from SKYEYE).
AIRTICI UAV (Figure 8) was tested in the inspection of an HV power line pole near Setubal. The UAV was equipped with visual camera for snapshot photos, thermographic camera and a small LiDAR system. The current solution is able to autonomously follow predefined waypoints but it has shown to be very dependent on the pilot, as is absent of collision avoidance sensors or other of the safety functions that already appear in quadcopter models.

Figure 8 – AIRTICI UAV.

UAVISION has been developing its own UAV solutions from the scratch and currently has several electrical models, from small 4-rotor UAV to bigger 6-rotor solutions. The UAVISION have the capability of following predefined waypoints. They also have a set of interesting safety functions, namely collision avoidance sensors and the possibility of standing in the air or returning to a predefined safe zone whenever the command radio connection is lost or the autonomy gets lower than a predefined level.

UAVISION made a demonstration in a MV (30 kV) overhead power line near Torres Vedras with a 4-rotor quadcopter solution (Figure 9) equipped with a camera for visual inspection. The device is smaller and hence easier to control than AIRTICI solution, but it showed serious stability problems flying closer to the conductors. A further analysis conducted by UAVISION revealed that electronics were not effectively blinded against the electromagnetic interference the UAV was submitted to during the flight.

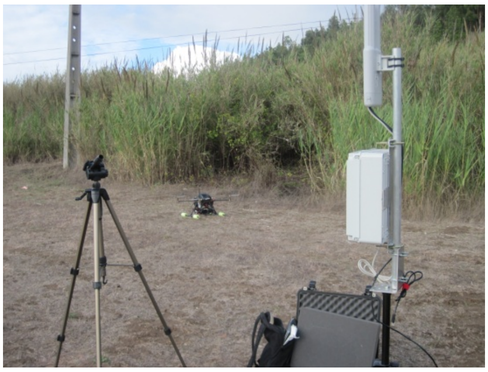

Figure 9 – UAVISION UAV.

SKYEYE is supplying a 4-rotor quadcopter UAV solution from a German manufacturer. It can be equipped with visual and thermographic camera and has a set of safety functions similar to the ones used by UAVISION (except for the collision avoidance sensors). SKYEYE performed a test flight in a MV (30 kV) overhead power line of EDP Distribuição. The UAV from SKYEYE (Figure 10) is more intuitive and easy to handle for the operator and revealed a more stable flight when compared with the other solutions tested by EDP Distribuição.

Figure 10 – SKYEYE UAV.

SKYEYE is offering two kind of business models: one in which the utility buys the UAV, has to ensure the licenses and assumes the risk of operating the device and another in which the utility only buys the service. In the latter option, SKYEYE has to ensure the licenses to fly, the maintenance of the device and assumes the operational risk.

CONCLUSION

After some years MAI inspections have been giving results that are appreciated by the utilities. A multi system helicopter MAI provides a wealth of information that leads to cost reductions in overall inspections. Still, a manned helicopter represents a considerable cost and this line of work involves considerable risks for the crew. So, efforts are being made to transfer some of the aerial inspections of power lines to UAV.

UAV solutions tested in EDP Distribuição power grid have as major bottleneck the inability to fly more than one span from the same command point. Indeed, current models require the operator to move from pole to pole in order to ensure that the safety distances to the live parts are maintained. This issue is expected to be gradually solved with the evolution of the safety functions and the accuracy of the flight control systems in following predefined waypoints. Other major concerns are the weather conditions to fly, namely maximum allowable wind speed and absence of rain, which turned to be a significant limitation considering that, these solutions could also bring huge benefits in fault detections during heavy weather conditions (saving time in moving teams in the field).

There are also other technical restraints regarding the payload allowed in a UAV, which limits the sensors it can carry in a flight, the UAV autonomies and the flight authorization for these aerial vehicles. A step by step approach, with the selection of proper sensors for the UAV and a vision of complementary inspections for UAV and MAI may be the scenery for the near future.

The data management algorithm has proven to facilitate the articulation between the three main agents involved in right-of-way clearance maintenance: the physical asset manager (EDP Distribuição) and the service providers responsible for the inspections and for resolution works. It also allows EDP Distribuição to meet its regulatory obligations and to optimize interventions by:

- Allowing prioritization levels
- Systematically defining the type of tasks required by each intervention
- Georeferencing intervention points, to support the service provider tasks
- Allowing a higher budget control
- Optimizing costs of present and future right-of-way clearance maintenance tasks

First results coming from more than one year of implementation suggests that large savings can be achieved by surgically intervening only in the detected anomalies, instead of blindly contracting the right-of-way clearance of large fractions of the overhead lines.

Furthermore, this method is aligned with the current EDP Distribuição risk based maintenance policies as it facilitates the collection of important information regarding the overhead lines condition, required for the decision making process. Thus, investments or maintenance procedures can be delayed, anticipated canceled or reinforced depending on the results obtained.