# ROBOTIZED INSPECTION OF OVERHEAD POWER LINES BY UNMANNED HELICOPTER

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**Abstract**

***Aerial inspection of overhead power lines carried out by helicopter is a routinely task in the field of transmission lines maintenance allowing the majority of components to be examined through video imaging recorded on board. These kinds of inspections have showed good efficiency. However drawbacks of this methodology related to risk of airborne personnel and high operating costs make that responsible people of inspections look at other options. In this report a new method, based on an unmanned helicopter, is presented. This method has been developed and demonstrated in the frame of the so-called Pelicano project funded and developed by Red Electrica de España (Spain) and AIN_tech (Spain). The result of the project is an unmanned aerial system, helicopter type, specialized in the intensive inspection of power lines. This system is able to provide an image quality equivalent or superior to that obtained by manned helicopter, it is cost-effective and minimizes the consequences in case of accident. The system is available to come into operation and its continued improvement will increase inspection capabilities and improve efficiency.***

## 1. INTRODUCTION

Aerial inspection of overhead power lines[1] carried out by helicopter is a routinely task in the field of transmission lines maintenance. Different airborne visible and infrared imaging systems sensors (EO/IR) are used depending on the type of inspection. In the case of visual inspection pictures taken from the helicopter allow the majority of components to be examined. The images are recorded and can be analysed later. Broken insulators and strands, wear of fittings, defective or loosened spacers and missing or drooping dampers can be detected by this method. In the case of infrared inspection, overheating problems related to false contact, dirtiness or oxidation are identified. These kinds of inspections have showed good efficiency. However two main drawbacks of this methodology should be taken into account. On one hand the operation of the airborne system (helicopter and payload) in the line environment is considered as a risky task. The helicopter has to operate at low altitude near cables which are no good seen in the air by the pilots. Fatal accidents can become frequent and the maintenance staff is increasingly reticent to this methodology. On the other hand, the operating cost of the whole system, helicopter and a high resolution gyro-stabilised EO/IR system along with the involved personnel (pilot, inspector and camera operator) is very high.

## 2. PELICANO PROJECT

In response to this situation in Spain, Red Eléctrica de España (REE), the Spanish Transmission System Operator (TSO), supported by Aerial Robotics Group of AIN (Spanish Technological Center) launched in 2003 the called Pelicano project with the objective of demonstrating the aerial robotic inspection of power lines by rotary wing unmanned aerial vehicles (helicopters).

In particular, the Pelicano project aims to develop an intensive inspection system of overhead power lines that using an unmanned and autonomous helicopter, allows to obtain intensive inspections that are at least equal in quality to those currently obtained by REE, and are made in the same period with costs below those currently obtained in the intensive inspection of lines with helicopter.

## 3. POWER LINE INTENSIVE INSPECTION

Power line intensive inspection is a type of aerial inspection specified by REE that consist of the filmation by high quality image, in the visible spectrum, of different components of the line in order to identify its faults. These include:

- Conductor condition, **broken strands**, abrasion, twists, foreign bodies, corrosions etc.;
- Connectors and joint condition;
- Fittings condition: clamps, spacers, vibration dampers, bolt tightening, position, locking devices, counterweights, aerial warning devices
- Earth wire condition, broken strands, abrasion, twists, foreign bodies, corrosions etc.;
- Fittings condition of earth wire;
- Insulator string verticality, number of insulators, position and eventual lack of locking devices;
- Conditions of cleanness, cracks, splits and bubbles in the insulators;
- Support condition, verticality, completeness of members, bolts, washers, nuts etc.:
- Foundations condition, breakage, cracking, vegetation, landslides, burials

Some examples about the required quality imaging in the intensive inspection of power lines are shown at the following pictures.

Articulated suspension clamp

Suspension insulator

## 4. PROJECT PHASES

In order to attain project objectives different sub-projects with intermediate objectives were carried out. First phase of the project (2003-2006) demonstrated the ability for precise navigation of a small, internal combustion engine powered helicopter in the environment of loaded overhead power lines and to send in real time good quality of video information to a ground control station. Second phase of the project ( 2007-2009) demonstrated the capability of an unmanned helicopter, called UAR-35, of 80 Kg MTOW and 1,5 h endurance to carry out intensive inspections ( high quality imaging) of overhead power lines with similar quality imaging than obtained by manned helicopters. Once technical feasibility was demonstrated, a third phase during 2010 about a technical-economical evaluation in a real case of 60 Km of a power line was completed with successful results. Finally in 2011 was launched the final phase of the project about putting in service of the system.

During 2011, 340 Km of intensive inspection were completed obtaining the required information for the correct interpretation and identification of defects in this kind of inspection.

## 5. PROJECT RESULTS

The strong requirements imposed by the application of power lines intensive inspection, both from the standpoint of image as robot navigation in an electromagnetic environment, has been the reason for the attainment of a very particular unmanned aerial system (UAS)[2]. This system is characterized by its high precise flight control system (FCS), able to operate close to the cables ( its "natural environment"), with extra capabilities for managing electromagnetic fields generated by the power lines and able to supply high quality imagery from tower components and cables. Therefore, in simple terms it can be said that the result of the project is an unmanned aerial system, helicopter type, specialized in the intensive inspection of power lines.

### 5.1.System description

From point of view of UAS general architecture the system is a conventional UAS system which consists of two major subsystems:

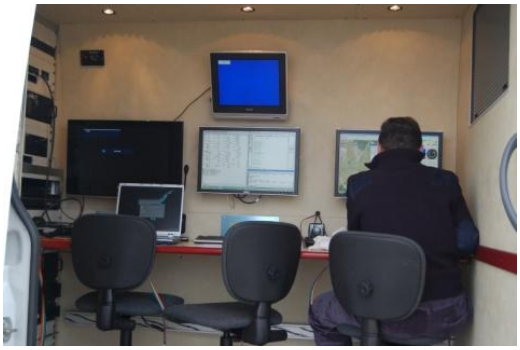
- The aerial segment ("robot" or "carrier") is composed of the aerial platform (helicopter airframe), the flight control system (FCS) based on an INS / DGPS navigation system, data link and gyro stabilized camera system.

  The main features of the carrier are shown in the following table:

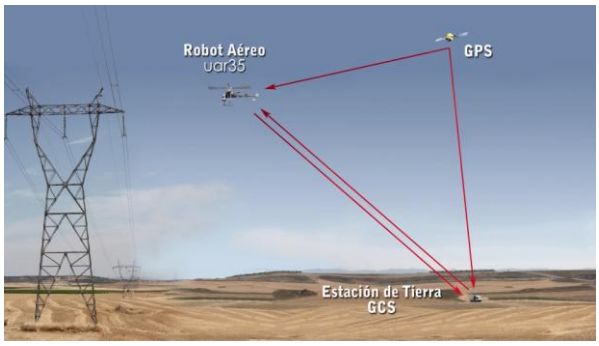
| UAR-35 | |
|---|---|
| ROTOR | |
| Main rotor blade diameter/ Blade number | 3,3 m / 2 |
| Tail rotor diameter/ Blade number | 0,45 m / 2 |
| Stabilizer | Bell-Hiller |
| FUSELAGE | |
| Length incl. both main rotor & tail blades | 3,9 m |
| Width | 0,85 m |
| Height | 1,1 m |
| ENGINE | |
| Displacement | 125 cc |
| Maximum power / rpm | 22 hp / 9.500 |
| WEIGHT | |
| Maximum Take-Off Weight (MTOW) | 80 Kg |
| Maximum payload weight incl. Fuel | 35 Kg |


UAR-35 Carrier

- The ground segment is a mobile ground control station (GCS) installed in a 4x4 vehicle. This system hosts communications systems as well as hard/software for command and control of the aerial robot. Another important subsystem is the GCS software. Each flight is previously planned with the Mission Planning module. The whole trajectory is planned on a georeferenced map by way-points. A simulation software module allows simulating the flight to verify that there are no errors in the planning.



Ground Control Station




Operational concept

### 5.2.System operation

The system has two operating modes: automatic and remotely piloted. Both are fully independent. The normal mode of operation is automatic. In this mode the robot is able to take off and land automatically and follow a path previously defined by waypoints. Although the robot is totally autonomous, during flight, at all times, from the ground station, it is possible to modify the planned route, for example for a fine approach to the tower in order to perform proper inspection of electrical components. The remotely piloted operation mode is an emergency operation mode in case of a widespread failure in the flight system. It is a totally independent of the previous system with a separate communications system and additional stabilization systems that allow a pilot to fly safely the robot to the ground station

### 5.3.System capabilities

The system is autonomous in terms of navigation and dispose of redundant systems for assuring safe operation under a global navigation strategy that includes, between others actions the “go home”. A special navigation module allows the robot to identify severe electromagnetic fields and accommodate robot trajectory to maintain a safe flight path. Current data link allow an operation radius of 5 Km line of sight (LOS) for this application. In combination with current endurance (1,5 h) continued inspection of 5 Km lengths of line is possible. Next generations of Pelicano systems will tend to extend operation radius and endurance in order to improve inspection efficiency.

Camera system provides gyrostabilization <35µ line of sight and 530 TV lines horizontal resolution. Video information is sent in real time to de GCS and digitally recorded on board at the same time.

### 5.4.System performance as a tool for power lines inspection

From point of view of TSO the result of the project is a tool for the intensive inspection of overhead power lines by helicopter that provides an image quality equivalent or superior to that obtained by manned helicopter and is cost competitive with the current solution, with the following advantages:

- Minimizing the consequences in case of accident due to be "unmanned" and maximum takeoff weight of 80 Kg
- Reduction of environmental impact:

  •Less noise and less consumption (reducing emissions)

  •Low impact on birds wildlife (smaller)

  •Ability to conduct inspections in areas of high ecological value

## 6. RESULTS EXPLOITATION

Taking into account the origin and motivation of this project, the use of the results of this project is directed towards the inspection of powerlines on a competitive basis with the current method using conventional helicopter. The system in its current state of development has proven its capabilities and potential for inspection. However, reliability must be improved both to increase inspection capacity and reduce maintenance costs, primarily related to mechanical issues.

The business plan associated with the exploitation of the results is based on the generation of revenues from inspection services. Initially a high percentage of them will be devoted to continuous improvement of the system which will result in an increasingly more efficient one. At the time of writing this paper the process of attracting partners and investors has been started.

Obviously the system can be used in other less demanding applications different than inspection of power lines. In this sense, the system is being successfully applied in remote sensing applications related to water management such as leaks and filtrations in hydraulic infrastructures and waste storage facilities, identification of water needs over irrigated fields, detection of discharges and emissions in water bodies etc[3]...

## 7. CONCLUSION

The power lines inspection system developed, based on an unmanned helicopter has demonstrated its ability to perform inspections of power lines equivalent to those currently performed by manned helicopter. The unmanned solution is competitive with the current one with the advantage of a considerable reduction of damage in case of accident. The system is available to come into operation. The continued improvement of it will increase its inspection capabilities and improve efficiency.

## References

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