Long Range Unmanned Aircraft System for Power Line Inspection of Brazilian Electrical System

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Abstract: Power line inspection is an essential procedure in the power lines maintenance area, especially thinking about service availability and energy efficiency. Aerial inspection of electric power transmission lines is typically performed using human-piloted helicopters, which is a procedure that is both expensive and prone to accidents taking risks to human beings' lives. The work presents a solution based on UAS (unmanned aircraft system) for inspecting power lines. In this context a R & D project of an unmanned aircraft system to be used for performing complete aerial inspection of overhead power lines is being executed by ITA (Instituto Tecnológico de Aeronáutica) (Technological Institute of Aeronautics) in Brazil. Special attention is dedicated to the communication system conception in order to comply with Remotely Piloted Aircraft System definition in the context of long endurance operations of the system. It presents a solution based on LTA (lighter than air) platform in order to extend the communication range beyond line of sight.

Key words: UAV, UAS, RPAS, power line, maintenance, inspection.

1. Introduction

Having one of the largest aerial power lines structures of the world with length as much as 95,000 km long, there is a large demand for aerial inspection of these structures in Brazil. The work is related to the Autonomous Robots area, in this case aerial robotics, applied to electrical engineering and aiming to develop a new method of long range aerial inspection of power lines.

The R & D project in development at ITA (Instituto Tecnológico de Aeronáutica) is sponsored by a Brazilian Electrical Company located in northeast of the country. CHESF (Companhia Hidro Elétrica do São Francisco) belongs to Eletrobrás which is the government electrical company. CHESF is responsible for power lines structures with total length above 20,000 km [1].

PL (power line) inspection is the beginning activity of the maintenance cycle and its effectiveness is

important for determining system reliability and the maintenance costs of the electrical system.

Means for inspection of the technical process of verification of the PL, its components and around, taking in account the established standards with the objective of detect defects and anomalies that prejudice the PL performance, its life time and people safety.

In the context of PL Inspection there are several types of performing related actions, but in this work there is a special interest in aerial inspection which is performed by manned helicopters in the conventional way. This traditional method is effective, but is prone to accidents and is a high cost method for inspecting power lines.

The main objective of the project is to provide a low cost solution for aerial power line inspection based on unmanned vehicles which have to be able to perform long range flights in a relatively short time. Special efforts are applied in order to keep the pilot on the ground linked to the plane all the time during the inspection.

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2. Unmanned Aircraft System

Nowadays, the international nomenclature for the system based on a unmanned aircraft is RPAS (remotely piloted aircraft system) which is comprised of three fundamental segments: aerial, communication and ground [2], as illustrated in Fig. 1.

2.1 Aerial Segment

Consist of the plane including: arframe, aerodynamic surfaces, propulsion, autonomous flight control and payload, which in this application is comprised of an imaging system and a video transmitter for sending the captured images to the ground segment.

The flight control system comprises autopilot, actuators and transceiver. The autopilot can read data available from inertial and pressure sensors, and from the GNSS receiver. The data are processed by the autopilot that sends control signals to the actuators and performs the control and navigation of the aerial platform. The flight plan is uploaded on the ground just before the take-off of the RPAS and the actuators act directly in the control surfaces and in the throttle of the propulsion system. Although the plane is able to fly autonomously, the RPAS concept has a piloting requirement that consists in a human pilot monitoring the flight all the time who is able to change the flight plan and finish the mission if necessary for safety reasons.

2.2 Communication Segment

It comprises the interface between the aerial segment and the ground segment, basically by means of a data link and a video link.

The data link is responsible for sending commands from the ground station to the plane and receiving telemetry on the ground station from the plane. In this way the human pilot has the necessary situational awareness for deciding about commands that would be necessary to send to the plane.

Fig. 1 RPAS segments.

The video link is necessary for transmitting live video the Data Application Station which is managed by the PL inspector.

2.3 Ground Segment

It is comprised of the GCS (ground control station) and the DAS (data application station). It is always necessary that GCS is the position where the human pilot work, getting telemetry signals from the plane and sends commands for controlling the plane. DAS is the position of the PL inspector who can watch the live video, control the camera gimbal and identify the defects.

3. Inspection Platforms

The project is defined in a very pragmatic approach based on development prototypes [3].

The Delta II platform is shown in Fig. 2 and is a model that was useful for integrating the avionics and imaging systems. Fig. 3 shows the image on the display of the GCS, highlighting the flight plan defined by waypoints and the on line telemetry indicating the position of the plane and other primary data.

For getting and additional experience with a typical UAV platforms, it was used in a purchased platform and the systems that were integrated in it. Fig. 4 shows the Delta III platform.

In addition, aiming to comply with the high level requirements of the project, it has been developed an own platform named Delta IV whose development prototype is shown in Fig. 5. This platform has to comply with constraints related to low flight speed and enough payload capability.

Fig. 2 Delta II inspection platform.

Fig. 3 GCS computer display.

Fig. 4 Delta III inspection platform.

4. Imaging System

The studies related to the imaging system were developed considering the specific application and three regions were defined: safety zone, IR zone and visible zone [4].

The safety zone was defined considering the risks of crashes of the plane to the PL and towers. The safety distance is referred as D_1 as shown in Fig. 6.

The IR Zone refers to the maximum distance for getting images in the infra red spectrum which is important to detect hot spots. The respective distance is referred as D_2 as shown in Fig. 7.

The visible zone refers to the maximum distance between the plane and the LT in order to capture images with necessary quality. This distance is referred as D_3 as shown in Fig. 8.

The three zones can be superimposed highlighting the intersection between IR zone and visible zone where the plane has to fly in order to satisfy both criteria, respecting the safety zone. Fig. 9 shows the zones intersection.

Fig. 5 Delta IV inspection platform.

Fig. 6 Safety zone.

Fig. 7 IR zone ($D_2 > D_1$).

Fig. 8 Visible zone ($D_3 > D_2$).

Fig. 9 Final composition.

5. Communication System

The high level requirement of long endurance RPAS defines a very severe constraint that is a challenge for the project. In fact, the electrical system has PL sections (between two substations) up to 350 km and it is important to cover the maximum length by means of one mission (take-off/landing cycle).

In this case the complete solution delivered by the project team has to comprise the long range communication requirement.

The concept illustrated in Fig. 1 is appropriate just for LOS (line of sight) communication which is not the case in this application.

The proposed solution for BLOS (beyond line of sight) communication is illustrated in Fig. 10, considering the usage of a tethered balloon working as a communication relay [5].

This low cost solution extends the communication range of the RPAS several times the LOS conception depending on the altitude of the balloon, the terrain and the performance of communication equipments.

In addition to the communication relay functionality, the tethered balloon can be used as a Pseudo UAV for communication test purposes [6].

The idea is to replace the plane by one tethered balloon equipped with the communication system designed for being integrated in the plane. Together with the communication equipments of the GCS it is possible to validate the communication link for especially remote positions in order to ensure that the RPAS concept will be complied for the specific mission [7, 8].

Fig. 11 illustrates the usage of the balloon as a Pseudo UAV.

Fig. 10 Long range communication solution.

Fig. 11 Balloon as a pseudo UAV.

6. Conclusions

The intended application presents high complexity considering several aspects of the project.

6.1 Positioning System

The application requires flights with low altitude and proximity to the power lines leading to an additional requirement regarding GNSS accuracy.

In addition, the topography is quite relevant for the flight plan because if it is not appropriately considered the plane can be guided to a crash to the terrain.

6.2 Imaging System

Considering a low cost approach for the camera gimbal, it is necessary to fly inside a very limited zone in order to capture and transmit images in both visible and IR spectrum. The corresponding distance is very short and leads to sub-item A where the positioning system requirements were discussed.

Another requirement related to the imaging system is the maximum speed of the plane which has to be less than 60-70 km/h. This requirement is controversial considering that the low cost inspection would be more cost effective with high speed of flight. It is necessary to balance and optimize flight speed and images' quality.

6.3 Communication System

It is necessary to pay special attention to the requirements related to RPAS concept and inspection live video regarding long range communication necessarily BLOS.

The immediate solution based on satellite communication implies in expensive communication bandwidth for live video leading to a low cost solution based on tethered balloon which is not outstanding because the altitude is not so high that can be compatible to dimensions of Fresnel zones. Anyway the proposed solution is a very interesting trade-off

aiming the effectiveness and costs as drivers of the analysis.

6.4 Balloon Based Test Methodology

The solution based on balloon working as a Pseudo UAV has been used for validating the communication equipments and links obtaining a method for measuring the communication capability of the system for long range communication without risks normally associated to high distances between the plane and the GCS.

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