Development of New Unmanned Fixed-wings Aircraft Patrol to Power Transmission Line

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***Abstract*—In connection with the shortcomings of the current power transmission line inspection Unmanned Aerial Vehicle (UAV), a new electric power inspection fixed-wing UAV is developed to improve the efficiency. The images of the line defects and potential problems are located and collected with the aerial views of the cameras. Combined with the GPS of the transmission tower, an autonomous flight inspection and airborne image real-time display is presented according to the default track points. The real-time image is considered as instructions to deformat UAV wings and achieve low-speed and low-altitude detailed inspection of the key parts of the circuit. It is able to self-control over-continent flight for 3 hours and it can be used to conduct ground and relatively small mountain ranges, plains region of daily patrol and large area electric power line disaster monitoring word.**

Keywords-unmanned fixed-wings aircraft; transmission line inspection; wing deformation; image acquisition; lift drag ratio

I. THE PROBLEMS OF CURRENT TRANSMISSION LINE UAV

In recent years, with rapid development of national economy, the reliability of power supply requirements is getting higher and higher. In order to ensure the safety and reliable operation of transmission lines, maintenance of automation and modernization has become increasingly urgent. Traditional manual inspection has heavy workload and difficult conditions, especially for the mountains and rivers of the transmission lines. Some patrol is inconvenient to complete by conventional methods, using unmanned aerial vehicles(UAV) for the grid line inspection has become an important means.

Currently, UAV used for power line patrol focused on unmanned aerial vehicles, helicopters and small unmanned rotorcraft[1-5]. The flight speed of Fixed-wing UAV is relatively fast, which can reach 100 to 200km/h , it has long life time so can be used for long distance transmission line to patrol the overall situation, but it can not hover , the inspection is only a single direction along the fast speed. Small rotorcraft has light weight, simple structure, designated take off and landing, hovering in the air , but its flight speed is slower and life is very short , usually the fault segments have been identified , usually the use of small rotorcraft can hover , low-speed and point- to observe the details of the fault identified, while its load is too small and wind capacity is weak. Helicopter can takeoff and land in the specific point, hover in the air , but flight speed is not as good as fixed-wing UAV , most less than 100km/h , the battery life is shorter too, so it's not suitable for long distance transmission line , the most advantage is that it can carry more testing equipment to obtain a more comprehensive inspection results, but the price is higher than smaller rotorcraft , usually used in short-distance transmission line or fault segments identified for detail detectability with hover style. Combined with fixed-wing UAV and helicopter for patrol, the inspection results will be more comprehensive , accurate, and can reduce the transmission line's missing , but the cost is higher. Typically, UAV can carry lots of low-speed, low-altitude flight in suspected drone, and ensure high-speed cruising , long census in the normal patrol route segment while power line inspection.characteristics said are two different flight conditions of the aircraft, it can not have both. Therefore, new requirement of the UAV for designing and developing is proposed, it can not only achieve heavy unmanned flight, but also reduce drag at light loads to reduce energy consumption; it can not only ensure high-speed low-drag large range cruising, but also for low-altitude fine inspections. This paper developed a new power line patrol UAV to solve these shortcomings.

II. DESIGN OF NEW FIXED-WING UAV AND TRANSMISSION LINE INSPECTION SYSTEM

New fixed-wing UAV with deformed wing patrol system is achieved based on the research of transmission line inspection requirements by the North China Electric Power University research team. UAV body's mechanical structure is simple, light weight, easily manipulated , highly efficient , easily maintenanced, etc., it can quickly maneuver to perform inspection tasks. While conducting power line patrol ,it can ensure a large range cruising speed on the line

corridor for rapid global survey for normal segment, and perform passing the line , tower for fine local inspection at suspected location at a low-speed, low altitude style.

New fixed-wing UAV inspection system is divided into five major subsystems, mainly including fixed-wing UAV subsystems, inspection mission equipment subsystems, remote telemetry subsystem, intelligent data management and analysis subsystem, deformed wing subsystem, the overall structure is shown in Fig1 Design of new fixed-wing UAV inspection system

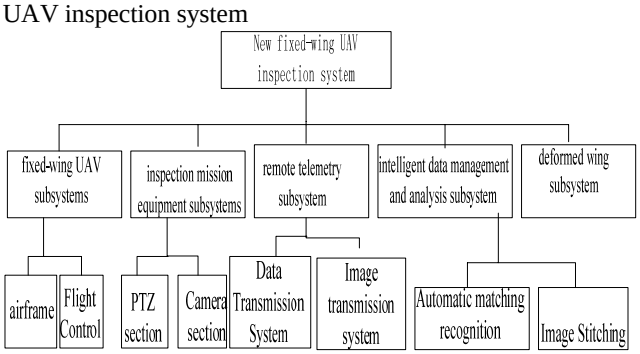

Fig1 New fixed-wing UAV system block diagram

A. *System features*

a) Fixed-wing UAV subsystems

Fixed-wing UAV subsystems is the flight carrier of inspection system, responsible for flight inspection missions , aircraft equipped with flight control systems, mainly including airborne sensors, onboard flight control computers and drives, Its function is drivering steering to control fixed-wing UAV by using solver control mission instructions from the ground station based on real-time fixed-wing UAV flight conditions.

UAV's aerodynamic shape uses conventional aerodynamic layout. Engine mounting position is in UAV 's first for the front pulling. UAV's landing gear uses tailwheel. The additional wing in the wings can expand or recover according to the flight need.

In order to meet the needs of the actual transmission line , fixed-wing UAV platform need to have some functions, including one -button self- rolling takeoff and landing, forward flight, climbing, diving, fixed height given radius circle and other functions, in accordance with pre- planned route three-dimensional fully autonomous flight . The main parameters are shown in Table 1 .

TAB I THE MAIN PERFORMANCE PARAMETERS OF NEW FIXED-WING UAV

parameters	new fixed-wing UAV
maximum takeoff weight/kg	35
engine / hp	2.6
life time/H	3
maximum flight speed/ $km \cdot h^{-1}$	95
minimum flight speed/ $km \cdot h^{-1}$	38
control radius/km	20
maximum range/km	240

b) Inspection mission equipment task subsystem

Inspection mission equipment task subsystem consists of PTZ system and camera control system. Video capture device is installed in the biaxial head by damping device mounted on fixed-wing aircraft bilge. When the aircraft maneuvers ,pitch and roll attitude changes, steering head angle can be output with the corresponding torque Attitude to maintain head angle remains fixed relative to the ground coordinate system , thus can ensure the shooting screen time to focus on the front part. Ground personnel can adjust the camera angle to focus on at any time through the PTZ control device, according to the merits of the screen image of line selected by capture devices .

c) Remote telemetry subsystem

Remote telemetry subsystem contains the data transmission system and the onboard video transmission system.Data transmission system uses wireless data transmission system[6-9], the ground station software decode control instructions, draw and generate track points. The signal is transmitted via the RS232 port to a digital transmission module ground terminal, it's encrypted, encoded, modulated to transmit power through airborne high gain antenna to ensure data receiving-side received, airborne receives FM signal by amplification and frequency modulation, the flight controlling system achieve an aircraft remote control by demodulating, decoding, decrypting in serial communication, so it can complete ground station's control command uplink transmission. Aircraft flight control computer collect all kinds of flight data , including camera mode (fixed distance, given time), whether to automatically return, GPS signal satellite number, route loop label, whether automatic landing, flight mode(manual remote control mode, automatic balancing mode, UAV navigation mode), current pressure altitude, distance to the current target waypoint, the offset to the current route from the GPS latitude and longitude measurements, the current target waypoint number, the current target course, the current target height , the current target speed, current routes starting latitude and longitude, heading and end of the current latitude and longitude, control battery voltage, time, current temperature, GPS refresh rate, digital radio refresh rate, pitch attitude, roll attitude, aileron rudder, throttle rudder, rudder quantity, the current oil, attitude errors, etc.adding the data package header to instrustions, which returns in serial mode via airborne terminal module, ground station software is used to identify various types of data and real-time display(monitor flight attitude), draw flight path, understand aircraft operation comprehensively, so it can achievein fixed wing UAV flight status data downlink .

The onboard video image transmission is the one direction data link to the land of airborne, including the transmission system and the receiving module, the image information of transmission line components is timely transmisstted by using the " non-line "," diffraction " transmission characteristics of COFDM (Coded Orthogonal Frequency Division Multiplexing) Image transfer mechanism, which can fully adapt to various environments

and has good anti-interference and noise immunity, it can be remote controlled acquire all-round multi-angle image datavia ground station to. Receiver can get image through the video decoding, image resolution, which is up to 1024 pixels × 960 pixels. It can meet the requirements of the latter image analysis, storage, editing, and provide an initial line maintenance information by post-picture analysis and processing.

d) ntelligent Data Management and Analysis Subsystem

Intelligent data management and analysis subsystem consists of automatic identification system and image stitching matching system[10]. Dynamic matching recognition is to find and match images of airborne detection equipment from the existing templates . Automatic matching system's main function is to determine the correspondence between the image and the tower in the post-processing of the image. Firstly, Import the image of airborne's into the database, then compare GPS information of airborne's image with the existing images in the template database. finally, use image analysis sub-system to analyze intelligently to find hidden defects and generate reports. Image stitching system can take pictures under the picture GPS, time, automatic splicing through tower model ,and generate the entire line corridor of high-definition images. It can effectively improve the detection accuracy, manage and inquire fault defect centralized by the automatic identification system and image stitching matching system

e) Wing deformation subsystem

Wing deformation subsystem can change the wing lift drag ratio according to the quality of load and jobs need, so it has both low resistance, high-speed cruising drones, high stability, and low speed to stay in the air.

The apparatus is designed increase lifting force: Refit wings in the middle of the wing near, add a layer of curved airfoill which can suddenly release backward in the original Karak Y-wing, When UAV need to fly at low speed and high aerodynamic staying in the air, the wing can be curved and released backward to provide additional lift force, The control system calculates the location of the horizontal tail's moving accordingly to ensure the stability of the UAV pitch. First, use aluminum to reinforce ribs, Installed 2 sets of worm transmission on the wing rib, Two retractable airfoil are hinged via worm wheel's front. Telescopic lift airfoil's path is limited by the track, the exprements results show that 2 retractable airfoil wing is released for 57 % of wing's chord length. Separated vortex on the convex of Karak Y will stabilize at retractable airfoil trailing edge, so it can Ensure controllability for flowing around of low aspect ratio's airfoil at low Reynolds. When the wing deform, control system will automatically launch airfoil's length of the deformed wing to bridle the real-time moving of horizontal tailplane. It can ensure UAV pitch's stability during wing deformation in-flight. It can achieve by controlling the deformation switch.

New fixed-wing UAV wing's structure before and after deformation is shown in Figure 2, within structure of the wing's deformation is shown in Figure 3:

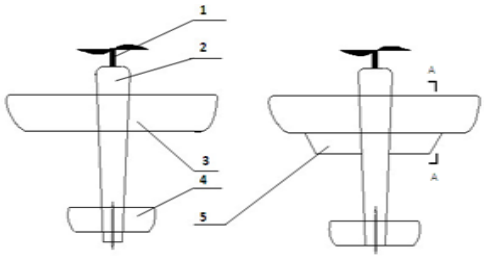

Fig2 New fixed-wing UAV wing's structure before and after deformation

1-Fuel Engines 2- Fuselage 3-Karak Y-wing 4-Horizontal tailplane 5-Additional airfoil

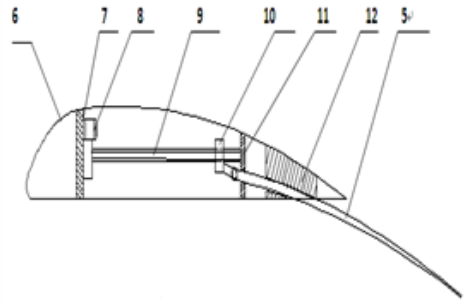

Fig3 within structure of the variability wing

6-Ribs 7-Front spar 8-Stepper motor 9-Worm 10-Turbine 11-Rear spar 12-Limitting track

Worm is placed on the bearing between the front and rear spar. Worm's rotation is driven by a stepper motor. Turbine is set on the worm and connected with an additional wing by a hinge To provide additional power for retractable airfoil, limit track is fixed in the wing ribs, rear spar has slit, slit and limit track control the trajectory of the additional airfoil jointly, the additional airfoil's releasing stroke is completed by inputting pulse signal to stepper motor, the signal is from control system, the releasing stroke can be flexibly adjusted to the actual operation of the UAV to change flight characteristics. control system can control both the launch and recovery of the additional wing stroke to ensure real-time control of UAV flight's characteristics; and control the horizontal tail wing's action accord with the additional wing to ensure pitch stability UAV is in the deformation.

III. DESIGN AND IMPLEMENTATION OF INSPECTION PROGRAM

A. Design of inspection function

For application requirements of transmission line inspection and focusing on the lines, towers , insulators, fittings and other parts of the image collection, the system uses strategy of a fully autonomous flight inspection to finish the task of the onboard video real-time display, aircraft parameter displaying, route planning, given fixed height and radius circling, automatic returning and remote control shooting.

Inspection system has some additional function: (1) Return in low oil. Flight control computer acquire real-time

oil level by reading sensor's parameters. If the oil level is lower than the preset of safe returning, ground control system will prompt and automatically send commands to the UAV to return and land autonomously, which can avoid accidents caused by lack of oil. (2) Protection for lost control of lost signal. When ground control signals can not be received due to accidental causes, aircraft can return and land autonomously. (3) Image's receiving and storage. Ground station software can display and store onboard real-time video to provide information for post analysis and processing. (4) Saving and exporting track point of UAV. save track points and route information selectively to provide a reference for the next transmission line inspection based on the merits of the last inspection results. (5) Return automatically. system can analog display monitoring and controlling radius, if the aircraft fly from monitoring and controlling radius , it will prompt and alarm, and flight control computer will send controlling commands and the UAV will return autonomously.

B. tests of inspection function

Autonomous flight track points can be preset according to GPS coordinates of the tower and the surrounding environmental conditions information. Route can be selected considering of a safe distance between line and tower, and imaging equipment's focusing distance too. UAV can deform when it flies to the key parts of lines referring to real-time airborne images returned, so it can achieve fine inspections at low altitude, track circling time and turning radius can be preset to complete hovering shooting on the relevant parts at each track point.

Aircraft trajectory can be updated by judging the merits of shooting angles and images based on real-time display of aircraft airborne image and ground vehicle parameter displayed. Ground handling personnel can set more optimized recording track points and GPS coordinates attitude angle , PTZ pitch angle and other information for the aircraft according to the current quality of the image captured to provide reference for the next inspection.

IV. APPLICATION PROSPECT

Power line disaster's monitoring is timely carried out in the event of failure, and patrol section is the segment or line. Possible points of failure can be prejudged according to the disaster situation or protective action, UAV flies to accident locations at the fastest speed, Wing deformat near the point of failure to reduce flight speed to perform sophisticated data logging in a given fixed height and radius hovering flight style.

Power lines routine inspections are conduct once a month, video camera and other functions are used to analyze and fill data of operating equipment, parts of the problem are record and reported to maintenance classes to exclude, for unidentifiable suspicious detail discovered, flight style of the given the fixed height and radius hovering at least 5S can be set to observe suspicious point carefully and shoot.

New fixed-wing UAV equipped with video equipment for power transmission line inspection is used. The novle wing deformation system is added, So it can not only ensure high-speed and large range cruising on the power line to achieve global census , but also pass the line and tower slowly to complete fine local inspection in suspected point, it can free the staff from the heavy inefficient daily manual inspection work, and save a lot of manpower and resources for the power companies in the power line transmission monitoring and routine inspections. Meanwhile, the UAV can also be used in spraying pesticide, geological exploration and other fields.

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BIOGRAPHIES

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