Design and implementation of an unmanned aerial vehicle to inspect power pylons by visual test (VT)

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Abstract

Power pylon networks are vital part of each country and they need regular inspection. The inspection operation usually is done by visual test (VT). This process takes time and energy and it may have several threats for inspector, so robots can do it. We made an unmanned aerial vehicle (UAV) which it can fly and carry necessary instruments for VT. This robot can be controlled remotely by operators. In this paper, convenient approaches for inspection and advantages and disadvantages of them were explained. Also the current pylon and power transmit equipment was introduced. After that, the new approach for inspection was presented. In this solution, the unmanned aerial vehicle (UAV) is used for monitoring and inspection of pylons. Then design and implementation steps are presented. These steps contain the mechanical, electrical and programing parts. In the next part, an inspection operation which was done by the robot is reported. Finally the ordinary inspection and robot inspection are compared together in terms of time, money, threats and quickness.

Keywords: Visual test, UAV, Power pylon inspection, Design, Implementation

1- Introduction

The electric distribution network (EDN) consists of pylons and cables that deliver electric power from power plants to users. Nowadays, EDNs are seen in all parts of the world [1]. Designing, manufacturing, installing and maintaining of EDNs are very important and complicate. Regular inspections and periodic maintenance are big challenges. EDNs are vast networks, so inspection is costly and time-consuming. In the past decades, the procedure of maintenance and repairing gradually are changed. The most important methods are used in Iran is as follows:

- Aerial inspection [2] (preventive): In this method according to the extent and importance of the network and condition of geographical area, helicopters are used to inspect. This method is a quick and a global inspection (figure.1).
- Tower inspection [2] (emergency): This method is usually used after failures that occur in EDNs. Inspectors repair damaged pylons or towers locally. This method takes more time and usually has life threatening. Therefore, inspection and climbing for technicians has dangers and costs (figure.2).

Figure 1. aerial inspection
According to the type of environment and level transition, there are power pylons with different heights. The height of high voltage pylons usually is 50 to 100 meters [1]. There are four major categories of transmission towers [1]: suspension, terminal, tension, and transposition. Some transmission towers combine these basic functions. Towers may be self-supporting and capable of resisting all forces due to conductor loads, unbalanced conductors, wind and ice in any direction. Such towers often have approximately square bases and usually four points of contact with the ground. Figure 3 shows structures of the suspension pylons.

2- The new approach for inspection

Today, robots are used to do tasks that are hard or impossible for humans. Accuracy and speed are advantages of robots in a mission [4]. The Unmanned aerial vehicle (UAV) is a branch of robots that can fly and collect information and send it to their land base. UAVs reach easily to out of access goals, so we can use these robots for inspection of electricity pylons [5]. In addition, because these robots are unmanned and remotely controlled, there is not any danger for technicians. These robots carry sensors and other detection equipment’s [6]. If a camera is mounted on the robot, it can collect and send images to the ground station [7].

2-1 Quadrotor

There are many types of UAVs based on the platforms. One of the most important types is the quad rotor. A Quad copter, also called a quad rotor helicopter or quad rotor, is a multirotor helicopter that is lifted and propelled by four rotors [8]. Quad copters are classified as rotorcraft, as opposed to fixed-wing aircraft, because their lift is generated by a set of rotors (vertically oriented propellers) [5&7]. Quad copters generally use two pairs identical fixed pitched propellers; two clockwise (CW) and two counter-clockwise (CCW) [3]. This configuration allows quad rotors to move easily in all directions and have excellent maneuverability. There are several advantages of quadrotors over similar scaled helicopters. First, standard quadrotors are mechanically less complex than helicopters due to the absence of the sophisticated rotor hub. This greatly simplifies the design and maintenance of the quadrotor. Second, the use of four small-diameter rotors (usually) allows quadrotors to possess less kinetic energy during flight as compared to helicopters. The thrust is controlled by modifying the rotational velocity of the rotors. As a rotor spins around its axis, an opposing torque (due to propeller blades aerodynamic drag) is generated around the rotor axis. In hovering or in vertical climb/descent, all rotors spin at the same speed. Due to the counter rotating nature of the two rotor pairs and the aforementioned symmetric property, the net torque on the quad rotor is zero; thereby no yaw motion is generated. Roll and pitch control can be achieved by increasing the speed of one rotor and decreasing that of the diagonally opposite rotor. The yaw control is achieved by the difference between the torques between a pair of opposite rotors and the remaining pair.
3- Design and implementation
3-1 Mechanical parts
The frame also must have a low weight, and good mechanical strength. In addition, the most important challenge to design structure is the center of mass balancing. Quad rotors frame shape is like a plus sign [3]. Four arms are joined to the central disk. The central disc consists of two parts, which are as bearing for each arm. The mechanical stress reduction of the central disk and the vibration reduction are the advantage of this design. After the calculation of the mechanical design, the detail design of the robot is drawn by software Solid Works (figure.5). The aluminum 6X is selected for fabrication. This aluminum has a good mechanical strength and low weight [6]. After selecting material, next step is implementation parts of the robot. The parts are produced by machining, grinding, polishing and drilling operations. Finally, the parts were assembled together according to the technical plan. (Figure 6-9)
3-2 Electronic parts
In this step, we tried to design a co-pilot to control the robot. A copilot should stabilize the robot, send and receive data [2]. A copilot consists of several sensors such as accelerometer, gyroscope and magnetometer, one or more processors and some peripherals [7]. The copilot consists of four units:
- Central processor unit
- Sensors
- Actuators driver unit
- Data receiver and transmitter

This part is the main parts of the copilot system and consists of a microprocessor. The task of the microprocessor is receiving and decoding sensor’s information, processing these data, and controlling the actuators [2]. This robot has a main processor and several sub processors, each of them has specific task. Sub processors, receive information from the ground base station and sensors, then decode them and send decoded data to the main processor. The main processor, process received data’s. Regard to the received orders by grand station, the main processor send command to the driver units. For real time control, the main processor must be high-speed. The Atmega-328 is selected for this purpose. This processor has high processing speed, tiny dimension and it can control several slave processors real-timely. Also, The Atmega-32 is selected as sub processor.

The tasks of Sensors in the robot are sensing and collecting necessary information. Because Quad rotors inherently are very unstable, sensors should sense the stability and statues of the system. The main sensors used in the UAV are the gyroscope and the accelerometer. The gyro sensor measures the angular velocity of the UAV in three axes. Accelerometer sensor can measure the linear acceleration [3]. Due to applications of UAV’s, various sensors, such as camera sensors, humidity gauges, pressure sensors, distance meter, global positioning system, can be mounted on the robot [4].

In flying robots, motors and propellers play main role in taking off mode. Therefore, they should have low weight and also produce enough thrust. In the robot, we have used brushless motors as thruster. Brushless motors like the other motors need to a driver. This driver unit also known as the speed control drivers. For driving the motor, the CPU should send pulses to the drivers. The frequency of the pulses is between 50 to 100 Hz and the pulse width is between 1 to 2 seconds. The increasing the pulse width, the increasing motors speed.

The communication unit sends and receives commands. A good connection should be stable, safe and has sufficient bandwidth. Using radio waves with appropriate wavelength is one of the most common ways to transmit information. A pair of commercially radio receivers and transmitters is used in the robot. Maximum range of transmission is about 3km and its frequency is 2.4 GHz, as well has 4 separate channels to send commands. The control loop is illustrated in figure.10.

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Figure 10. control process loop of the UAV
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3-3 Dynamic and control
The control type of the robot is semi-automatic control in this project. The necessary commends are sent to the robot by radio transmitter and ground station. According to the conditions and received commends, CPU controls motors. A flying robot in space has six degree of freedom, so it is very unstable. As well as, other factors such as non-balanced frame and non-identical motors increase instability of the system [8]. A closed loop control systems, such as PID and FUZZY is appropriate to control [9]. The PID controller system is simple to implement and is not complicated. This control system collects proportional, integral and derivative error and compare these errors, finally send proper commends to motors.
External noises reduction and improved performance are the most important challenges in controller design. For this purpose, the PID controller can be used [10]. A PID controller continuously calculates an "error value" as the difference between a measured process variable and a desired set point. The controller attempts to minimize the error over time by adjustment of a control variable [4]:

\[ u(t) = K_p e(t) + K_i \int_0^t e(\tau) d\tau + K_d \frac{de}{dt} \]  

Where \( K_p, K_i \) and \( K_d \), all non-negative, denote the coefficients for the proportional, integral, and derivative terms, respectively (sometimes denoted P, I, and D). In this model, P accounts for present values of the error, I accounts for past values of the error, and D accounts for predicted future values of the error, based on its current rate of change. The control loop is shown in figure 11.

\[ \text{Figure 11. PID loop control} \]

4- Results and Discussion
The simulation is used to evaluate the controller design and to find the best gains. The model is simulated by the MATLAB Simulink. According to the simulation, graphs of the results are plotted in figure 12. As it can be seen after a short while the robot is stabilized by the controller so the robot can fly and take capture in safe mode.

\[ \text{Figure 12. result of overshoot simulation} \]

To compare the new method with conventional method, figure 13 and figure 14 show the captured photo from a pylon. These photos are accurate and useful for inspection. In addition, figure 15 shows the capture photo by a thermal camera, so the visual test and thermography test can be done by this method. Table 1 compares these two inspection methods with other aspects.
5- Conclusions
In this paper, we propose a new method of power line inspection by using UAVs. Then one of the most important flying robots, Quad rotors, was introduced and its principal was discussed. The details of UAV functionality and communication systems are introduced and discussed. Our practical experience shows that by this cooperative operation, the time taken for inspection can be greatly reduced and the efficiency can be improved. The feasibility and superiority of UAV inspection is demonstrated. The further work may include the optimization of UAV configuration in crew team.

References