Design of UAV Autonomous Charging Pad for Surveillance

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Abstract

The conventional unmanned aerial vehicles have limited supply of power due to which they are grounded after designated hours of flight. In this paper, the autonomous charging of UAVs is proposed, developed, implemented to increase the battery charging and operational life. The development of automated charging system for UAVs is achieved by utilizing the solar based charging system by means of charging stations marked throughout the route of a UAV. The drone, according to the predefined programming, evaluates its charging level and when the level drops below the set threshold, it lands on a landing site. The UAV can charge itself through contact-based charging functionality without a human's interference. This allows the UAVs to stay in flight for longer periods of time and does not requires intervention of humans to change the battery pack. This will increase the efficiency in terms of surveillance and allows the legal agencies carrying out surveillance to maintain their cover and achieve footage which might have been lost while landing the UAV to change the battery pack. This system can perform surveillance to be carried out by a single UAV as it does not rely upon human's support for the supply of power. The improvement in the battery life allows UAVs to hover for longer hours thus avoiding the risk of crash landings and damage to the UAVs.

1. Introduction

The use of unmanned aerial vehicles (UAVs) has increased over the years allowing them to be used in various types of operations. The basic operations of UAVs include surveillance [1], and package delivery [2]. These are used by various industries especially the army to carry out rescue operations or to safeguard a nation. The UAVs have been a reliable source of operation especially in areas where man's life will be at risk or is not able to fly to [3]. The UAVs are convenient as they do not require a pilot operating internally thus allowing the possibility of a compact aerial vehicle. The operator can remotely fly a UAV and keep a watch over the target. These UAVs though being a convenient method of surveillance also has a major flaw, as their battery life is somewhat limited which hinders the flight time [4]. Each time the battery falls low from lower threshold level, the UAV has to be landed and an operator has to change the battery pack manually. This results in incomplete tasks specially in emergency surveillance and losing flight time that will directly affects the surveillance time. Also, an operator remains on a high alert throughout the flight duration, crash landing of the UAVs as highly equipped UAVs are expensive and being sighted by the party which is under surveillance.

One of the easiest methods to overcome this charging issue is to increase the battery size. Though this seems like a suitable idea but practically this is not. Increasing the battery size or the number of batteries increases the weight of the UAV which in return requires increased power to fly [5]. This also hinders the size of a UAV. When the number of batteries increased, the overall size of a UAV is increased which when used to carry out surveillance becomes highly visible. Other method to overcome this problem is to use a wire-based system to power it. The drawback of this method is that possible human intervention is required. Due to this, the overall system increases in size and becomes inconvenient in environments which do not support the existence of humans. The proposed research allows the charging of a UAV through an autonomous charging pad which utilizes the solar radiations to charge the batteries. One of the mega advantages of this technology is that the UAVs do not have to rely on a human's work efficiency. This allows UAVs to be charged in remote areas where setting up a human friendly base becomes impossible.

The remainder of paper is organized as under; in Section 2, the hardware design of the project is briefly explained categorizing in subsections (i) Drone Design and (ii) Solar Charging Station.

Section 3 defines the methodology of the project and focuses upon the charging and the connectivity of the UAV and the solar charging station. Section 4 concludes the paper and recommends future aspects for the project.

2. Hardware Design

UAVs are designed according to the environment they have to serve in. The most efficient and popular design is a quadcopter [6]. A quadcopter incorporates 4 brushless DC motors which allow it to hover above the ground or to fly above the ground depending on the specifications of the motors. These motors allow the rotorcraft to maintain high mobility and kinesis by operating the propellers. The factors which include the responsive maneuverability, vertical takeoff, and landing (VTOL) abilities, and soaring allows the quadcopters to fly both indoors and outdoors [7]. These unmanned vehicles require power supply like all other vehicles and instead of burning fuel, this fly using electrical power. The reason for using electrical power is to allow the UAVs to be limited in size, produce less heat and sound, and can be operated in almost every environment. These are the important factors which are to be achieved through an UAV. In this research, instead of designing a conventional charging station for a UAV, a contact based, wireless recharging station powered through a solar energy source was incorporated. The project is divided into two separate sections: (i) Drone Design (ii) Solar Charging Station (SCS) Design.

3. Drone Design

The drone, UAV, is built using conventional components including the frame, propellers, landing gears, electronic speed controller (ESC), flight controller (FC), brushless AC motors, rechargeable battery and its charger, transmitter and receiver, microcontroller and other essential electronic modules. With these, an additional part is added in the design which is the contact-based charging mechanism. The frame is the most crucial component of a drone [8]. The entire design relies upon the frame's integrity and strength. The material selected for the frame is a fiberglass material allowing it to be flexible, strong, and ultra-light all at once. As this is a quadcopter as seen in Figure 1, four 1024 propellers were used. The number 1024 states the specifications of the propellers. 1000 represents 1000 rotations per minute and 24 represents 24 cm defines the length of the blades. For each of these propellers, a separate brushless AC motor is used. The motion of the motors is controlled using an ESC which allows the speed control, rotation direction and the braking of the

motor. The signal sent to ESC is controlled using a FC which in turn is controlled through the microcontroller. Basic remote based transmitter and receiver as shown in Figure 2, allows the communication between the drone and operator. The drone requires electric power which is supplied through a rechargeable battery fitted upon the drone frame.

Figure 1 - Quadcopter's Frame
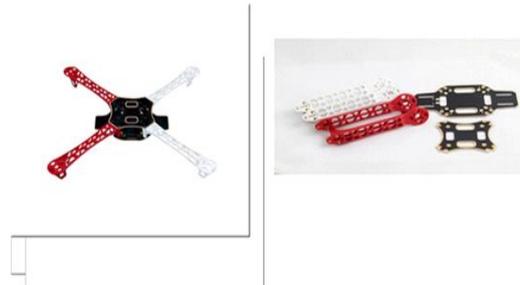
The charging of the battery upon contact with the solar charging pad is through the landing gears. One side of the gear acts as a positive node and the other side acts as the negative node. The entire representation of the quadcopter designed and tested in an open area due to its ease of operation is illustrated in Figure 3.

Figure 2. Transmitter and receiver

Figure 3 - Testing of Quadcopter

Basic Quadcopter: The ELEV-8

4. Solar Charging Station

The SCS consists of solar plates in order to make the charging environment friendly and conducting metal strips to allow the passage of current from the pad to the drone. The design is kept simple so that the complexity can be kept at minimum. The conducting metal strips serve as positive and negative terminals of the station and to allow the drone to create a successful contact, four strips are used with the first and third being the positive terminals and the second and fourth being the negative terminals. The back view of the SCS is shown in Figure 4.

Figure 4 - Rear side view of Solar Charging Station

5. Methodology

With the hardware in hand, a software was required to allow the control of the flights of the drone. A freeware software known as Mission Planner [9] was used for this purpose. The mission planner is a graphical user interface-based software allowing the user to monitor the location of the drone, to control and calibrate the flight, thus making landing points and to carry out test runs before the actual flight [10]. The software allows graphical analysis of the flights and creates planning simulations to provide an overview of the flights. Figure 5 shows the environment of the software. The entire system connectivity and operation can be understood through the flowchart in Figure 6. It summarizes the entire operation from the signals transmitted through the receiver to the flight of the drone.

Figure 5 - Mission Planner's Default Environment

Fig. 6 - System Block Diagram
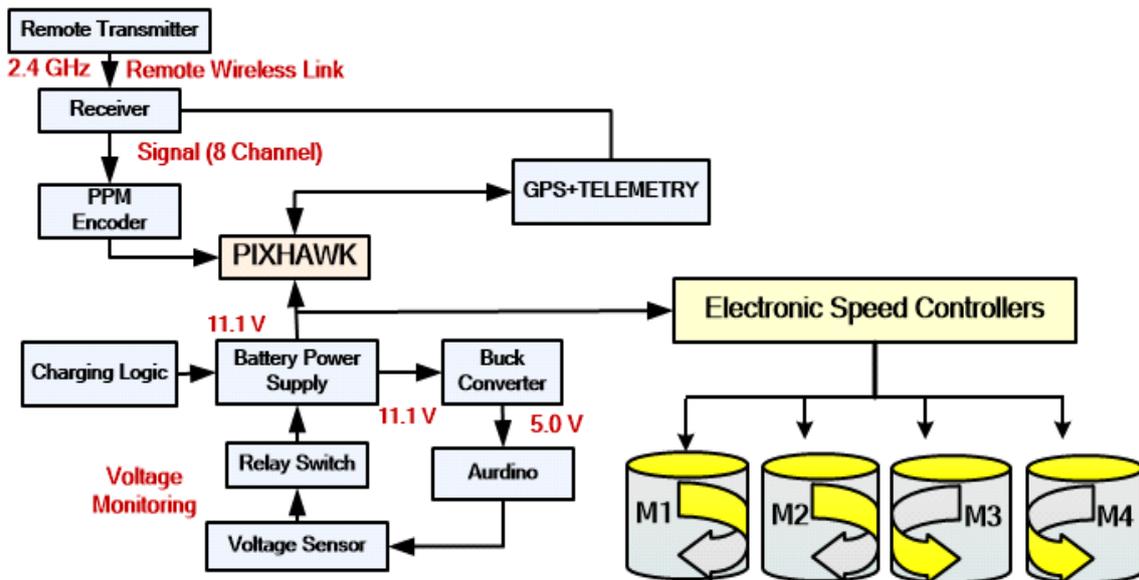
Figure 7 is the flowchart for the charging mechanism of the drone. It explains the interrelation between the SCS and the drone. The solar panel upon receiving the protons from the sunlight, charges the battery of the SCS. This charged battery supplies the voltage to the UAV when it successfully lands on the charging pad with the help of the charging circuit. The available supply voltage of the charging pad is monitored through the use of a voltage current* sensor which is operated by an Arduino.

Figure 7 - Charging Block Diagram
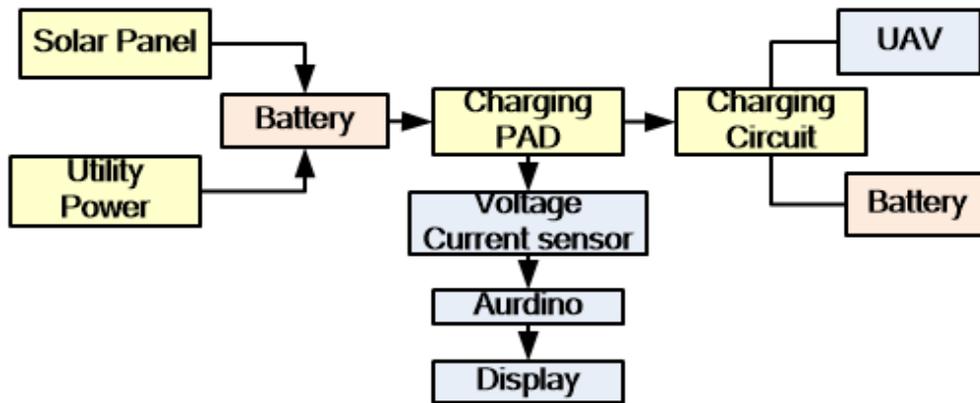
6. In-Flight Surveillance and Autonomous Charging

The charging cycle can be understood through the flowchart in Figure 8. As the drone takes off to do surveillance from the point of origin, the charging is continuously monitored through the use of a microcontroller.

Figure 8 - Charging While Midst the Flight
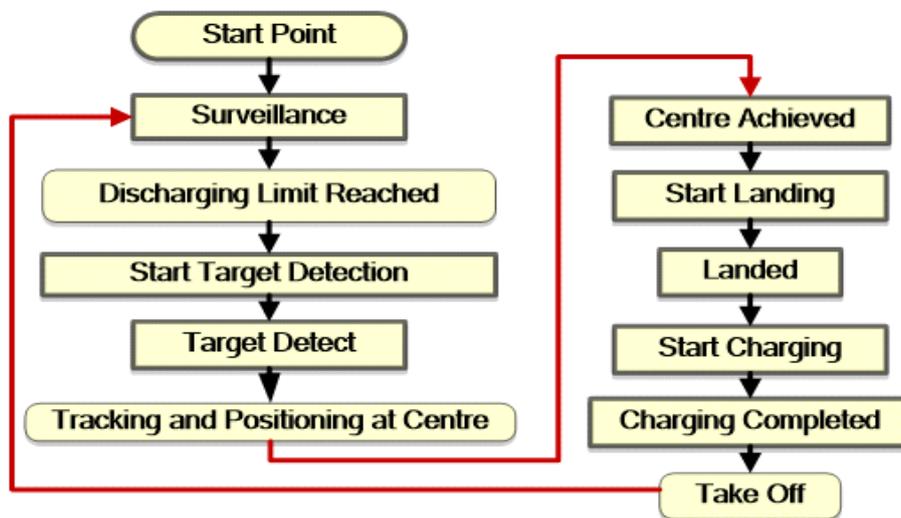
Once the discharge threshold is crossed, the drone with the help of global positioning system (GPS), locates the nearby SCS. The drone tries to land in the center by tracking the midpoint of the station. As the landing point is achieved, drone lands and as soon as the contact is made, the drone starts to charge. As the charged threshold is crossed, the drone takes off and continues on its surveillance path. The cycle is repeated until the mission does not ends. The entire flight is monitored

from the ground control system and any errors in the flight simulation or changes in the environment can be overcome by taking over the manual control of the flight.

7. SCS and UAV Connectivity

The landing position of the drone even after proper calibrations can be off due to multiple factors such as the environmental factors and the delay due to the GPS [11]. This resulted in an issue which was the improper landing of drone on the platform. Due to this, the terminals of the quadcopter and the plates on the station at times did not connect properly. To resolve this problem, the number of terminals on the platform were increased to four and the nodes were set in an alternative order with positive being the first terminal. Though this allowed the better chance of connectivity but created a separate issue. The landing gears on the drone could connect to reverse terminals which would create reverse voltage thus damaging the drone. The simple solution to this problem was to incorporate diodes in the design. Both forward biased and reverse biased diodes were used. When the positive terminal on the landing gear of the drone connects with the anode of the diode, only then the connection is marked as complete. Vice versa for the negative terminal on the drone's leg. The circuit is completed only when the negative terminal connects with the cathode of the diode. Figure 9 shows the incorporation of diodes in the design.

Figure 9 - Incorporation of Forward and Reverse Biased Diodes
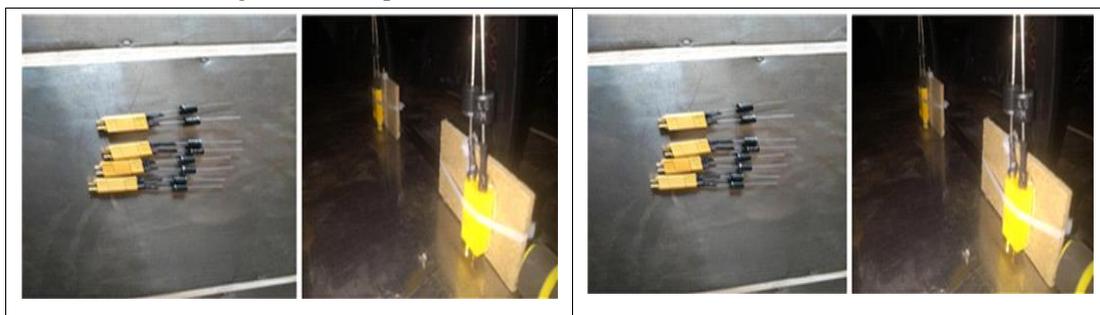
8. Conclusion

In the modern era, the incorporation of human interference is seen as a limitation in the performance of the model and a system. Methods are being explored with each passing day allowing the removal or at least the limitation of human component. The UAV in this research aimed at a similar goal. Normally, when a drone requires recharging, it is landed and a human either changes the battery set or connects it manually to a charging port. Though the process might not seem a hectic

concern but creates an inefficient system. Rather than hiring a human to perform such tasks, it is better to develop a system where the UAV does not require a human's interference. The work done in this research aimed removing the human component in the charging cycle. For this purpose, solar charging stations were developed allowing the drone to charge directly by landing on the station. This does not require additional connectivity through wires or human intervention to change the battery set. Once the terminals on the landing gear of the drone connect to the terminal of the charging station, the charging starts. This is triggered through the use of a microcontroller which signals a drone that it requires charging or is sufficiently charged and can carry on its mission. The efficiency of this design saves a lot of precious time and reduces human error. It also allows the charging of drones in areas where the human cannot survive or will face a hard time to reach. The system can be further improved by using better GPS maps and environment prediction facilities in both the drone and the stations. Another feature to add can be a mobile charging station allowing emergency charging of a drone with low power. With the passing time, the solution to many worldly problems is the automation of systems allowing the humans to remain safe and create an efficient world.

9. Acknowledgment

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