

UAV CHARGING SYSTEM

FIELD OF THE INVENTION

This invention relates to unmanned aerial vehicle (UAV) charging system and more specifically, but not exclusively, to a multirotor UAV charging system.

5 BACKGROUND TO THE INVENTION

Unmanned aerial vehicles (UAVs), also commonly referred to as drones, are aircraft which operate without a human operator onboard the craft. UAVs may be remotely operated by a human operator and may include autonomous capabilities of varying degrees to allow the UAV to conduct specific operations without a human operator. Without the
10 need for a human operator on board the aircraft, the size of UAVs may be decreased to conduct operations which would otherwise not be possible with UAVs which are large enough to have human operators on board.

Over the last few decades, multirotor helicopter UAVs have become very popular. Specifically, quadcopters which include four rotors, have proved to be a mechanically
15 simple and stable and with a decreasing cost of avionics and advances in battery and

electric propulsion, quadcopters are becoming the preferred platform for low-speed UAVs which operate in an autonomous fashion. Some applications of multirotor UAVs include aerial photography, surveillance, and inspection.

A problem with all electrically powered aircraft, and specifically with smaller multirotor UAVs, is that batteries have very low specific energy when compared to fuel used in internal combustion engines. In designing an electrically powered aircraft, there is a design trade-off between additional battery capacity (and consequently the flight time) and the payload of the aircraft. However, an increase in battery capacity and its consequent weight, will also have a negative effect on the manoeuvrability and speed of the aircraft. Where longer flight times are required, for example for the inspection of power lines over long distances, the increased weight and decreased manoeuvrability of a higher capacity battery, may make use of such a UAV infeasible.

OBJECT OF THE INVENTION

It is accordingly an object of this invention to provide a UAV charging system which, at least partially, alleviates the problems associated with the prior art or provides a useful alternative thereto.

SUMMARY OF THE INVENTION

In accordance with the invention there is provided a UAV charging system comprising:

- a primary UAV and an energy UAV;
- the primary UAV and the energy UAV having electric propulsion which is powered
5 by a rechargeable battery;
- the energy UAV battery having a relatively greater capacity than the primary UAV
battery;
- the energy UAV including a charging element extending from the energy UAV
which connects to a battery charger on one end and has a charging connector at
10 the other end;
- the battery charger being powered by the energy UAV battery;
- the primary UAV having a complementary connector for releasably connecting to
the charging connector such that when the complementary connector connects
to the charging connector, the battery charger charges the primary UAV battery;

- the system includes a guidance controller which controls movement of the UAVs and which, when required, moves the UAVs to a charging position wherein the charging connector engages the complementary connector and the primary UAV battery is charged from the energy UAV battery through the charging system.

5 The UAVs may be multirotor helicopters. The multirotor helicopters may be quadcopters.

The electric propulsion may be provided by four propellers driven by four brushless DC electric motors.

The charging element may include two or more conductors. The conductors may be charging wires.

10 The charging element may include a rod which extends operatively upwardly from the energy UAV.

The charging wires may be extendable such that, when the UAVs are in the charging position, the UAVs may move apart from each other and maintain the charging position and connection.

15 The extendable charging wires may be spring loaded.

The extendable charging wires may be on a spring loaded spool which can extend and retract the wires.

- The element may be movable between an active position, wherein the element extends upwardly from the UAV and, and an inactive position wherein the element is positioned
- 5 along the body of the UAV.

The connectors may create a mechanical connection.

The connectors may create an inductive connection wherein the connector includes an inductive coil and the complementary connector includes an inductive coil such that, when connected, energy may be transferred through inductive coupling.

- 10 The battery charger may generate alternating current for the inductive connection. The alternating current may be generated by an inverter connected to the energy UAV battery.

The connector and complementary connector may include magnetic elements for creating and securing the connection.

- 15 The connector may include an electromagnetic magnet.

The complementary connector may include a permanent magnet.

The guidance system may include a digital camera. The digital camera may be mounted on the primary UAV.

The guidance system may use images captured by the digital camera to determine the relative position between the UAVs and to move the UAVs to the charging position based on the relative position.

The lens of the digital camera may be coaxial with at least part of the complementary connector.

The system may include a plurality of energy UAVs wherein the guidance controller may move any one of the energy UAVs toward the primary UAV into a charging position.

BRIEF DESCRIPTION OF THE DRAWINGS

An embodiment of the invention is described below, by way of example only, and with reference to the drawings in which:

- Figure 1 is a upper perspective view of an energy UAV with a charging element in an inactive position;
- Figure 2 is an upper perspective view of an energy UAV with a charging element in an active position;
- Figure 3 is a lower perspective view of a primary UAV;
- Figure 4 is a lower perspective view of a primary UAV and an energy UAV in a charging position;
- Figure 5a is a perspective view of a second embodiment of a primary UAV and an energy UAV with a charging element in an active position;
- Figure 5b is a perspective view of the primary UAV and energy UAV of figure 5a in a charging position; and

Figure 6 is a perspective view of the primary UAV and energy UAV of figures 5a and 5b wherein the conductors of the charging element are extended.

DETAILED DESCRIPTION OF THE DRAWINGS

With reference to the drawings in which like features are indicated by like numerals, a UAV charging system is generally indicated by reference numeral 1.

The UAV charging system 1 includes a primary UAV 2 and a secondary energy UAV 3.

- 5 The primary UAV 2 and secondary UAV 3 shown in the figures are shown substantially similar in size. However, it is conceivable that the system will be equally as effective when the relative sizes of the UAVs are different whether the primary UAV 2 is larger or smaller than the energy UAV 3. Both the primary UAV 2 and the energy UAV 3 have electric propulsion which is powered by a rechargeable battery. The energy UAV battery
- 10 4 in this example is located operatively below the body 5 of the energy UAV 3 and the primary UAV battery is located within the body 5. Each UAV is a multirotor helicopter in the form of a quadcopter with four propellers 6 which are driven by brushless DC electric motors 7. The propellers 6 of the energy UAV 3 faces downward while the propellers 6

of the primary UAV 2 faces upward. The capacity of the energy UAV battery 4 is relatively greater than the primary UAV battery. This enables the primary UAV 2 to be lighter than the energy UAV 3 for increased payload carrying capacity or longer flight time.

The energy UAV 3 has a charging element 8 which is connected to a battery charger inside the body 5 on one end of the element 8 and has a charging connector 9 on the other end of the element 8. The battery charger is powered by the energy UAV battery 4. In the current example, the charging element 8 is in the form of a rod which extends operatively upwardly from the energy UAV 3 and includes conductors within the rod. The element 8 is movable between an active position (shown in figure 2) wherein the element extends upwardly from the UAV and, and an inactive position (shown in figure 1) wherein the element is positioned horizontally along the body of the energy UAV 3.

In this example, the primary UAV 2 has a complementary connector 10 on the underside of its body 5 which can releasably engage and connect to the charging connector 9. The complementary connector 10 may also be on the energy UAV, in which case the charging element will form part of the primary UAV 2. When the complementary connector 10 and the charging connector engage to form a connection, the battery charger charges

the primary UAV battery from the energy UAV battery 4. The charging connector 9 and the complementary connector 10 may form a mechanical connection wherein conductors on the charging connector 9 engage conductors on the complementary connector 10. Alternatively, as is the case in the current example, the connectors may create an

5 inductive connection wherein the charging connector 9 includes an inductive coil and the complementary connector 10 includes an inductive coil such that, when connected, energy may be transferred through inductive coupling. When the connectors form an inductive connection the battery charger may generate alternating current for the inductive connection by an inverter connected to the energy UAV battery 4. The charging

10 connector 9 and complementary connector 10 may include magnetic elements for creating and securing the connection. In the current example, the charging element 9 includes an electromagnet which is powered from the energy UAV battery 4 and may be selectively activated or deactivated, depending on whether the UAVs are in the charging position or not, and the complementary connector 10 has a permanent magnet.

15 In a second embodiment (shown in figures 5a, 5b, and 6) the charging element includes a rod 8 and extendable charging wires, or set of charging wires, which extend from the

charging element 8. This enables the primary UAV 2 and energy UAV 3 to form a charging connection in the charging position and allows the primary UAV 2 and secondary UAV 3 to move apart from one another once the charging connection is established. The extendable charging wires can extend and retract in a spring loaded
5 manner. Alternatively, the extension and retraction of the charging wires 11 may be actuated as and when necessary. In the example shown in figures 5a, 5b and 6 the extendable charging wires are on a spring loaded spool located within the energy UAV
3.

Once the charging connection is established, the charging element may be safely moved
10 to the inactive position (as shown in figure 6) and the UAVs may move relatively away from each other whilst the charging connection is maintained. The UAVs will ideally move far enough apart (as shown in figure 6) that the downdraft from the propellers of the primary UAV 2 does not impact or influence the propulsion of the energy UAV 3. Further, the propellers face downward on the energy UAV 3. This decreases the chance of
15 interference or entanglement of the charging wires with the propellers 6 of the energy

UAV 3. The charging connection may be disengaged once necessary and the extendable charging wires will be spooled back up on the spring loaded, or actuated, spool.

The system 1 includes a guidance controller which is in the form of electronic avionics equipment and software running thereon to control the movement of both the primary

- 5 UAV 2 and the energy UAV 3. The guidance controller may form part of the control system of either the primary UAV 2 or the energy UAV 3, in which case the guidance controller will be located within one body 5. Alternatively, the guidance controller may be external and be in wireless communication with the UAVs. The guidance controller is configured to control the movement of and between the primary UAV 2 and the energy
- 10 UAV 3 such that, when required, the UAVs may be moved to a charging position wherein the charging connector 9 engages the complementary connector 10 to form a charging connection. Once the charging connection is formed, the primary UAV battery is charged from the energy UAV battery 4. The charging position may be maintained until the primary UAV battery is fully charged, after which the primary UAV 2 may disengage and
- 15 break the charging connection. The energy UAV 3 may return to a base station or land until the primary UAV battery reaches a low charge. Once the primary UAV 2 reaches a

low charge, the energy UAV 3 may again be dispatched to the primary UAV 2 for charging.

The system 1 may also include multiple energy UAVs 3 depending on the operational requirements of the primary UAV 2. For example, where the system includes a base station with charging equipment for the energy UAVs 3, two energy UAVs 3 may be charging at the base station simultaneously. In this example, one of the energy UAVs 3 may be dispatched to the primary UAV 2 for charging and, after charging the primary UAV 2, return to the base station for charging the energy UAV battery 4. When the primary UAV 2 requires further charging, the second energy UAV 3 may be dispatched to the primary UAV 2 for charging, while the first remains at the base station to charge its battery 4. Depending on the charging times, capacity of the energy UAV batteries 4, and the operations conducted by the primary UAV 2, the primary UAV 2 may be kept airborne for an extended and possibly even indefinite amount of time.

The guidance controller may include a digital camera which may be mounted on the primary UAV 2. The guidance controller may use images captured by the digital camera to determine the relative position between the UAVs and to move the UAVs to the

charging position based on the relative position. This is required as the accuracy of the positioning system (for example GPS) of the guidance controllers may not have the necessary accuracy to ensure that a connection is formed. The guidance controller may also make use of real-time kinematic positioning (RTK) to increase the accuracy of the

5 system.

It is envisaged that the invention will provide a UAV charging system which enables primary UAVs to be lighter and better equipped to deal with its operational requirements whilst ensuring increased airborne time through charging with one or more energy UAVs.

The invention is not limited to the precise details as described herein. For example,

10 instead of quadcopters, the UAVs may be multirotor helicopters with 6 or even more rotors. Further, instead of brushless DC electric motors driving the propellers, regular DC, AC, or induction motors may be used.

CLAIMS

1. An unmanned aerial vehicle (UAV) charging system comprising: a primary UAV and an energy UAV; the primary UAV and the energy UAV having electric propulsion which is powered by a rechargeable battery; the energy UAV battery having a relatively greater capacity than the primary UAV battery; the energy UAV including a charging element extending from the energy UAV which connects to a battery charger on one end and has a charging connector at the other end; the battery charger being powered by the energy UAV battery; the primary UAV having a complementary connector for releasably connecting to the charging connector such that when the complementary connector connects to the charging connector, the battery charger charges the primary UAV battery; the system including a guidance controller which controls movement of the UAVs and which, when required, moves the UAVs to a charging position wherein the charging connector engages the complementary connector and the primary UAV battery is charged from the energy UAV battery through the charging system.

2. The UAV charging system of claim 1 wherein the primary UAV and the energy UAV are multirotor helicopters.
3. The UAV charging system of claim 2 wherein the multirotor helicopters are quadcopters.
- 5 4. The UAV charging system of claim 1 wherein the electric propulsion is provided by four propellers driven by four brushless direct current (DC) electric motors.
5. The UAV charging system of claim 1 wherein the charging element includes two or more conductors.
6. The UAV charging system of claim 5 wherein the conductors are charging wires.
- 10 7. The UAV charging system of claim 6 wherein the charging wires are extendable such that, when the UAVs are in the charging position, the UAVs may move apart from each other and maintain the charging position.
8. The UAV charging system of claim 7 wherein the extendable charging wires are spring loaded.

9. The UAV charging system of claim 8 wherein the extendable charging wires are on a spring loaded spool which can extend en retract the charging wires.
10. The UAV charging system of claim 1 wherein the charging element includes a rod which extends operatively upwardly from the energy UAV.
- 5 11. The UAV charging system of claim 1 wherein the element is movable between an active position, wherein the element extends upwardly from the UAV and an inactive position wherein the element is positioned along the body of the UAV.
12. The UAV charging system of claim 1 wherein the charging connector and the complementary connector create a mechanical connection.
- 10 13. The UAV charging system of claim 1 wherein the charging connector includes an inductive coil and the complementary connector includes an inductive coil and the charging connector and the complementary connector create an inductive connection such that, when connected, energy may be transferred through inductive coupling.

14. The UAV charging system of claim 13 wherein the battery charger generates alternating current for the inductive connection.
15. The UAV charging system of claim 14 wherein the alternating current is generated by an inverter connected to the energy UAV battery.
- 5 16. The UAV charging system of claim 1 wherein the charging connector and complementary connector include magnetic elements for creating and securing the connection.
17. The UAV charging system of claim 16 wherein the charging connector includes an electromagnet.
- 10 18. The UAV charging system of claim 16 wherein the complementary connector includes a permanent magnet.
19. The UAV charging system of claim 1 wherein the guidance system includes a digital camera.
20. The UAV charging system of claim 19 wherein the digital camera is mounted on
15 the primary UAV.

21. The UAV charging system of claim 19 wherein the guidance system uses images captured by the digital camera to determine the relative position between the primary UAV and the energy UAV and moves the UAVs to the charging position based on the relative position.
- 5 22. The UAV charging system of claim 19 wherein the lens of the digital camera is coaxial with part of the complementary connector.
23. The UAV charging system of claim 1 wherein the system includes a plurality of energy UAVs and wherein the guidance controller moves any one of the energy UAVs toward the primary UAV into a charging position.