BRIEF DESCRIPTION OF THE DRAWINGS

[0006] Non-limiting and non-exhaustive embodiments of the invention are described with reference to the following figures, wherein like reference numerals refer to like parts throughout the various views unless otherwise specified. Not all instances of an element are necessarily labeled so as not to clutter the drawings where appropriate. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles being described.

[0007] FIG. 1 is a perspective view illustration of a demonstrative UAV that has landed on a charging pad in accordance with some embodiments of the present disclosure.

[0008] FIG. 2 depicts a block diagram showing components associated with generation and use of power communication to regulate charging of the UAV of FIG. 1 in accordance with some embodiments of the present disclosure.

[0009] FIG. 3 depicts a block diagram showing components included in the battery(ies)/BMS and CRB in accordance with some embodiments of the present disclosure.

[0010] FIG. 4 depicts a block diagram showing components included in the charging unit in accordance with some embodiments of the present disclosure.

[0011] FIG. 5 depicts an example process for achieving battery charge regulation without inclusion of battery charge regulation components in the UAV and using the same lines/wires/conductive traces/pins as used for power transmission to batteries included in the UAV in accordance with some embodiments of the present disclosure.

[0012] FIGs. 6A-6B depict example circuitry included in a switch in accordance with some embodiments of the present disclosure.

[0013] FIG. 7 depicts an example encoding scheme of the charge rate data in accordance with some embodiments of the present disclosure.

[0014] FIG. 8 depicts example charge rate data encoding waveforms in accordance with some embodiments of the present disclosure.

SUMMARY OF INVENTION

[0014a] According to a first aspect of the present invention, there is an apparatus comprising:

a plurality of electrical contacts, wherein first and second electrical contacts of the plurality of electrical contacts are configured to electrically couple with a charging

device external to the apparatus, wherein the apparatus comprises a vehicle;

one or more rechargeable batteries configured to be charged with power received, via the first and second electrical contacts, from the charging device; and

circuitry configured to obtain battery state information associated with the one or more rechargeable batteries during charging of the one or more rechargeable batteries and generate battery charge rate data based on the battery state information,

wherein at least one of the first or second electrical contacts is coupled to the circuitry to transmit the battery charge rate data to the charging device over the at least one of the first or second electrical contacts used to receive the power for charging the one or more rechargeable batteries, and wherein the battery charge rate data is configured to be used by the charging device to regulate charging of the one or more rechargeable batteries.

[0014b] According to a second aspect of the present invention, there is 12. A system comprising:

a charging pad;

an unmanned aerial vehicle (UAV) including at least one rechargeable battery and a plurality of electrical contacts, wherein the UAV is configured to land on the charging pad and establish electrical contact between the charging pad and two or more electrical contacts of the plurality of electrical contacts;

a power supply external to the UAV and electrically coupled to the charging pad, the power supply configured to provide power to the two or more electrical contacts of the plurality of electrical contacts, wherein the power charges the at least one rechargeable battery; and

a charging unit external to the UAV and electrically coupled to the charging pad and the power supply, the charging unit configured to determine and control a level of the power provided by the power supply based on charge data associated with the at least one rechargeable battery that is generated by the UAV and communicated to the charging unit over at least one of the two or more electrical contacts used to provide the power for charging the at least one rechargeable battery.

DETAILED DESCRIPTION

[0015] Embodiments of a system, apparatus, and method for generation and use of power communication to regulate charge of unmanned aerial vehicles are described herein. In the following description numerous specific details are set forth

CLAIMS

What is claimed is:

1. An apparatus comprising:

a plurality of electrical contacts, wherein first and second electrical contacts of the plurality of electrical contacts are configured to electrically couple with a charging device external to the apparatus, wherein the apparatus comprises a vehicle;

one or more rechargeable batteries configured to be charged with power received, via the first and second electrical contacts, from the charging device; and

circuitry configured to obtain battery state information associated with the one or more rechargeable batteries during charging of the one or more rechargeable batteries and generate battery charge rate data based on the battery state information,

wherein at least one of the first or second electrical contacts is coupled to the circuitry to transmit the battery charge rate data to the charging device over the at least one of the first or second electrical contacts used to receive the power for charging the one or more rechargeable batteries, and wherein the battery charge rate data is configured to be used by the charging device to regulate charging of the one or more rechargeable batteries.

2. The apparatus of claim 1, wherein the circuitry is further configured to encode the battery charge rate data in the power provided by the charging device over the first or second electrical contacts.

3. The apparatus of claim 1, wherein the circuitry comprises:

a diode; and

a first switch coupled in series with the diode,

wherein the circuitry is configured to encode the battery charge rate data in the power by closing the first switch in a particular pattern.

4. The apparatus of claim 1, wherein the battery charge rate data is encoded using first, second, third, and fourth pulses, the first and second pulses separated by a first time, the third and fourth pulses separated by a second time, and the second and third pulses separated by a third time.

5. The apparatus of claim 4, wherein the first time indicates a current command associated with charging the one or more rechargeable batteries.

6. The apparatus of claim 4, wherein the circuitry is configured to indicate a validity of the battery charge rate data to the charging device by generating the first time equal to the second time.

7. The apparatus of claim 3, further comprising:

a second switch coupled in parallel with the diode,

wherein the circuitry is configured to open the second switch and close the first switch when encoding the battery charge rate data.

8. The apparatus of claim 1, wherein the first and second electrical contacts comprise fewer than all of the plurality of electrical contacts.

9. The apparatus of claim 1, wherein the vehicle comprises an unmanned aerial vehicle (UAV) and the charging device comprises a charging pad, and a power source, and wherein the first and second electrical contacts electrically couple with the charging pad when the UAV lands on the charging pad.

10. The apparatus of claim 1, wherein the circuitry is configured to periodically update the battery charge rate data.

11. The apparatus of claim 1, wherein the vehicle comprises an autonomous vehicle and the autonomous vehicle lacks circuitry for regulating a charging current or a charging voltage of the power for charging the one or more rechargeable batteries.

12. A system comprising:

a charging pad;

an unmanned aerial vehicle (UAV) including at least one rechargeable battery and a plurality of electrical contacts, wherein the UAV is configured to land on the charging pad and establish electrical contact between the charging pad and two or more electrical contacts of the plurality of electrical contacts;

a power supply external to the UAV and electrically coupled to the charging pad, the power supply configured to provide power to the two or more electrical contacts of the plurality of electrical contacts, wherein the power charges the at least one rechargeable battery; and

a charging unit external to the UAV and electrically coupled to the charging pad and the power supply, the charging unit configured to determine and control a level of the power provided by the power supply based on charge data associated with the at least one rechargeable battery that is generated by the UAV and communicated to the charging unit over at least one of the two or more electrical contacts used to provide the power for

charging the at least one rechargeable battery.

13. The system of claim 12, wherein the UAV further includes circuitry configured to obtain battery state information associated with the at least one rechargeable battery during charging of the at least one rechargeable battery and generate the charge data based on the battery state information.

14. The system of claim 13, wherein the circuitry is further configured to encode the charge data in the power provided by the power supply.

15. The system of claim 13, wherein the power comprises a direct current (DC) current-controlled voltage, wherein the circuitry includes a switch coupled in series with a diode, and wherein the circuitry is configured to encode the charge data in the power by closing the switch in a particular pattern.

16. The system of claim 12, wherein the power supply comprises a direct current (DC) current-controlled voltage source.

17. The system of claim 12, wherein the charge data indicates at least one of a current, a voltage, a battery charge rate, battery state information associated with the at least one rechargeable battery during charging, or data usable by the charging unit to regulate charging of the at least one rechargeable battery.

18. The system of claim 12, wherein the charging unit is configured to determine a validity of the charge data by comparing time periods between pairs of pulses on the power.

19. The system of claim 12, wherein the charging unit is configured to leave the power unchanged when the charging unit determines the charge data is invalid by comparing times periods between pairs of pulses on the power.

20. The system of claim 12, wherein two or more of the charging pad, power supply, and charging unit comprises a unitary device.