A critical review on unmanned aerial vehicles power supply and energy management: Solutions, strategies, and prospects

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Abstract

This article investigates many different methods of recharging drones, and different battery types and analyzes the benefits and downsides of these charging methods and battery types. Some of the charging methods are swapping, where one drone is flying while another is charging, and they swap when the one flying runs out of energy, hot swapping, where one drone has it's empty battery replaced with a full one, Laser-beam inflight recharging, where an on ground power source uses a laser to transfer energy to the drone, and tethered UAVs, where a drone is constantly plugged into a power source, with a long cord, so it never runs out of energy. The article examines compressed gas fuel cells vs batteries as a source of energy, and while fuel cells can last far longer than traditional batteries, the mechanical nature of fuel cells results in delayed response time for the drone's energy needs. In situations where large amounts of energy are needed, electronic batteries tend to be superior due to their faster response time, and higher power output per kilogram. The article suggests that a hybrid fuel source may be ideal, where the UAV uses electronic batteries in times of high energy demand, such as takeoff, or maneuvering, and a hydrogen fuel cell during times of low energy needs such as when cruising.

Materials & Methods

A review of published research evaluated electric unmanned aerial vehicle (UAV) power supply configurations and energy management systems (EMS). The analysis included studies on lithium polymer (LiPo) batteries, polymer electrolyte membrane fuel cells (PEMFCs), solar cells, and supercapacitors. Literature addressing hybrid power systems and auxiliary endurance extension methods, including battery swapping, laser-beam inflight recharging, and tethered power systems, was also considered.

Comparative analysis was done by collecting and analyzing performance characteristics from existing experimental and theoretical studies. These included reported values of energy density, power density, refueling/recharging times, and endurance limitations. Additional methods included evaluating active and passive power management strategies through previously published experimental results and computational models. Studies on fuzzy logic, rule-based, and optimization-based EMS strategies were also developed to provide insight into current and future trends in UAV power management.

Analysis

The review found key trends in UAV power supply development. Lithium-polymer batteries are the most widely used source due to their high energy density and low weight, but they limit flight times to under 90 minutes for small UAVs (Boukoberine et al., 2019). Fuel cells offer more energy than batteries (meaning longer flights), but hydrogen storage presents safety, weight, and cost challenges. Hybrid systems that integrate fuel cells with batteries or supercapacitors have shown to consistently balance endurance with rapid response to peak loads. (Boukoberine et al., 2019).

Alternative recharging approaches, including battery swapping and laser-beam in-flight charging, extend operational time but require significant investment in infrastructure (Boukoberine et al., 2019). Swapping stations enable continuous UAV operation but increase system complexity and battery turnover. Laser charging prototypes achieve over 12 hours of flight but are constrained by line-of-sight and altitude limitations. Tethered UAVs provide theoretically unlimited endurance but are restricted to small operating zones (Boukoberine et al., 2019).

This information is useful for a science fair project focused on drones or rovers designed to pick up trash in parks because it highlights the importance of choosing the right power system for endurance and efficiency. For instance, a battery-powered rover may be enough for small-scale displays, but for longer missions, hybrid systems like solar charging could allow for extended operations without as many interruptions. Understanding the trade-offs between endurance, weight, and power management is crucial for designing a practical and effective autonomous vehicle.

References

Boukoberine, M. N., Zhou, Z., & Benbouzid, M. (2019). A critical review on unmanned aerial vehicles power supply and energy management: Solutions, strategies, and prospects. *Applied Energy*, *255*, 113823. https://doi.org/10.1016/j.apenergy.2019.113823