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Overview of Solar UAV Power System

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Abstract: In this work highlights the differences of solar drones in different space states. In mission missions, low altitude drones are generally used for mapping due to their flexibility and mobility. High-altitude drones, due to their high flying altitude and long endurance, are used for military functions such as reconnaissance, intelligence gathering and surveillance. Based on the advantages of super-long range and high-altitude operation, the adjacent space UAV can be used in natural disaster early warning, emergency rescue and relief, and communication systems. Through the development of solar UAV in recent years, this paper analyzes the challenges of different space states from the aspects of solar cell conversion efficiency, battery performance and aircraft skin.

Keywords: Solar drone, Power system, Space type.

1. Introduction

In recent years, solar energy has entered human production and life as a new type of clean energy. So far, solar products have emerged in an endless stream. Solar drones are unmanned aerial vehicles that continuously fly at high altitudes using solar radiation energy. It uses photovoltaic cells to convert solar energy into electrical energy, and drives the propeller to rotate to generate flight power, so as to meet the production needs of human beings. According to the type of space, drones can also be divided into low-altitude drones, high-altitude drones, and near-space drones. In daily life, low-altitude drones are generally used for surveying and mapping. Due to the flexibility and mobility of low-altitude drones, they not only meet the needs of my country's surveying and mapping industry, but also greatly improve the service quality of the surveying and mapping industry. Therefore, how to improve the long-endurance flight of low-altitude UAVs is a problem that needs to be solved. The flight height of high-altitude UAVs is generally about 20km. Due to its high flight height and long battery life, it is used for reconnaissance, intelligence collection, surveillance and other military functions. Carrying out research on high-altitude UAVs to seek breakthrough technologies can quickly occupy the new energy UAV market. Near space is between the aircraft flight area and the spacecraft operation area. Based on the advantages of ultra-long range and high-altitude operation, near space UAVs can be used in natural disaster early warning, emergency rescue and disaster relief, and communication systems. It can be seen that the research on solar drones plays an extremely important role in expanding practical applications and seizing the drone market.

2. Development History of Domestic Solar Drones

The first solar-powered unmanned aerial vehicle "Soar" in China is mainly developed by the team of Dr. Li Xiaoyang and Professor Zhao Yong. The "Soar" is 1. 25 m long, 1. 88 m wide, and has a flying height of 1 000-1 500 meters. A total of 120 monocrystalline silicon solar cells are laid on the wing of the aircraft, which uses a special nickel-metal hydride battery as an energy storage system[1].

Later, Mozi I was jointly developed by a Shanghai company and Tongji University in 2015. The aircraft has a wingspan of 14 m, a solar panel laying area of about 10 m2, and a payload of 7 kg. Later, due to a broken wing during a test flight, the Mozi II aircraft was born. This model has a wingspan of 15 m, a flying height of 8 000 m, and can operate continuously for 12 hours under ideal conditions. Increase[2].

In 2016, UAS EXPO CHINA demonstrated my country's new solar-powered UAVs (3. 3 m composite wing VTOL solar UAV and 4. 4 m fixed-wing solar UAV). These two UAVs use the world's leading thin-film solar energy Battery, GaAs thin-film solar cells with light, thin, soft, and high-efficiency characteristics are especially suitable for solar UAV systems. Therefore, compared to conventional pure battery drones, this solar-powered drone extends the battery life to 6-10 hours.

The high-altitude long-endurance solar UAV Rainbow, independently developed by the Eleventh Research Institute of China Aerospace Science and Technology Corporation, completed the near-space flight test in 2017 [3]. This research makes my country the third country after the United States and Britain. countries that have mastered this technology. The UAV has a wingspan of 45 m, a battery life of up to 24 hours, a mission load of 20 kg, and a flight altitude of more than 20,000 m. Its performance is second to none among similar domestic solar-powered UAVs [4].

To sum up, although the research on the solar UAV energy system in my country started relatively late, the domestic research on the solar UAV energy system has achieved good results in the world. It is believed that in the future development of science and technology, my country's solar UAV energy system will achieve more achievements.

3. Key Technologies

3.1. Suitable for low-altitude UAV solar cells

A solar cell is an optoelectronic semiconductor sheet that uses sunlight to generate electricity directly, also known as "solar chip" or "photovoltaic cell", abbreviated as PV in English. As long as it is illuminated with certain illumination conditions, it can instantly output voltage and generate current in the presence of a loop. Solar cells can be divided into crystalline silicon solar cells, thin film solar cells,

amorphous silicon solar cells, compound solar cells, organic solar cells (polymer solar cells), dye-sensitized solar cells according to the different production materials [5],The principle of photovoltaic cell generating current is shown in Figure 1. Solar energy forms new hole-electron pairs on the semiconductor p-n junction. Under the action of the electric field in the p-n junction, the photogenerated holes flow to the p region, and the photogenerated electrons flow to the n region, and the current can be generated after the circuit is turned on.

The working height of low-altitude drones is generally between 100-1000m. Facing the changeable weather factors in low-altitude conditions, solar cells must not only have high conversion efficiency, but also have good wind resistance, high/low temperature resistance, Corrosion resistance and other key properties. Solar cells also need to consider their quality, thinness, and ductility. so that it can be laid on the surface of the aircraft. At present, most low-altitude drones use thin-film monocrystalline silicon solar cells. This flexible thin-film solar cell has the advantages of being bendable, unbreakable and low in quality, but its conversion efficiency is relatively low. At present, thin-film solar cells have great application prospects in the market, and its development is very important for the development of low-altitude UAVs.

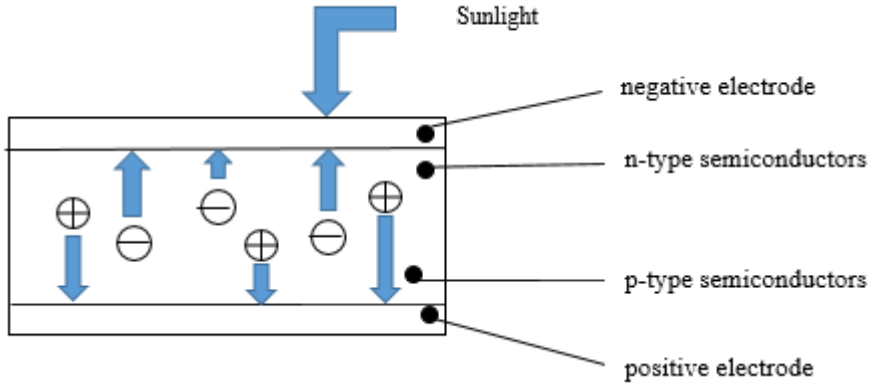

Figure 1. Principle of current generation by photovoltaic cells

3.2. Suitable high-altitude UAV solar cells

First of all, high-altitude long-endurance UAVs have the following characteristics:

High flying height: The flying height of high-altitude drones can reach 1000-2000m. Compared with low-altitude drones, it has a stable space state and stable illumination, which is more conducive to the use of monitoring equipment.

Long battery life: Due to the high flight altitude and the stable existence of light energy, if the energy stored by the drone during the day is greater than the energy consumed at night, it can theoretically continue to fly at high altitudes. Therefore, a battery with high conversion efficiency and large energy storage should be selected.

Large body size: It is understood that today's high-altitude solar drones need to lay as large a thin-film solar cell as possible on the body because of their large energy requirements, resulting in the continuous increase of the body size, in order to achieve the purpose of high battery life.

The performance of solar photovoltaic cells, especially the conversion efficiency, is one of the decisive factors for the performance of solar drones[6], Silicon solar cells are the most used solar cells. Monocrystalline silicon solar cells have stable properties, and the conversion efficiency can reach 16%-18%. The conversion efficiency of polycrystalline silicon is slightly lower, and can also reach 15%-17%. The requirements of high-altitude and long-endurance solar drones for solar photovoltaic cells are not only high conversion efficiency, but also good high and low temperature resistance, radiation resistance, corrosion resistance and reliability. At the same time, in order to ensure that the aerodynamic efficiency of the wing will not be affected after paving, the solar cell must not only ensure the same shape as the aircraft skin, but also ensure that the wing closely fits with the skin after the wing is deformed by force, so the flexibility of the solar cell is also critical.

There is also a crucial factor affecting the flight time of high-altitude UAVs: the performance of the energy storage battery. In order to meet the needs of drones operating at high altitudes at night, the demand for energy storage batteries needs to increase, so as to achieve more daytime energy storage.

At present, the main application of high-altitude drones is lithium batteries. As shown in Figure 2, lithium-ion batteries are lighter than other batteries for the same amount of energy stored. The addition of polonium to lithium-ion batteries has a more stable cycle life and a lower self-discharge rate, but the disadvantage is that the energy-to-weight ratio increases.

At present, although the energy density of lithium-ion batteries is very high, they only meet the basic needs of high-altitude drones. By combining other elements with lithium-ion batteries to obtain longer lifespan, new batteries with greatly improved energy density are the
key.

Table 1. Comparison of different types of batteries

Battery Type	sodium sulfur battery	Lithium sulfur battery	Lithium Ion Battery	Lithium-Pollium Ion Batteries
Operating Voltage/V	2. 1	2. 5~1. 7	3. 7	3. 7
energy to weight ratio/ (Wh/kg)	120~250	350~600	100~250	130~200
cycle life/frequency	>2500	>100	400~1200	>1000
Operating temperature/Celsius	300~350	-60~60	-20~60	-20~60
self-discharge rate		<15%	8%~31%	5%

3.3. Applicable Near Space UAV Solar Cells

The solar cell of the near-space long-endurance UAV is affected by its power density and laying area, which leads to the limited energy that the battery can provide. As a part of the skin of the UAV, the solar cell needs to carry a certain aerodynamic load. Because of its poor rigidity, small thickness, and brittleness and cracking, the requirements for the wing are very high. The battery will also be damaged when the wing bends a lot during the process[7].

Therefore, near-space drones need a stable battery laying platform, and at the same time solve its installation problems. This large-scale UAV solar cell has a large laying area and relatively high process requirements. To develop such a UAV, it will invest a huge amount of time and money.

For now, this near-space drone still needs a more optimized design. Such drones often carry a lot of large equipment to complete tasks such as atmospheric monitoring, reconnaissance surveillance, disaster detection, and Internet services. Therefore, a longer battery life is required. Not only should its battery function be outstanding, but its aerodynamic design should also be optimized to ensure that it can work longer and more efficiently. At the same time, in order to meet human needs, it can be designed with functions such as stealth.

4. Conclusion

Driven by related science and technology, solar-powered UAVs are developing rapidly. This article discusses the functions of different space types of solar-powered UAVs and the difference in battery technology, and points out the development direction of battery technology on UAVs. The development of UAVs is relatively good, and conventional UAV technology has been unable to meet the needs of new aircraft. Therefore, under the current conditions of rapid scientific development, it is still necessary to solve the problems in the field of UAVs and carry out innovative research to make our country's UAVs have a broader space for development.

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