Wireless Charging and Endurance Platform of Patrol UAV Based on Inductive Power Collection of Transmission Line

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Abstract. This project designs a wireless charging and endurance platform for patrol UAV based on inductive power collection. The main function is to solve the problems of short dead time and continuous inspection of ordinary patrol UAV. The system is mainly composed of transmission line inductive energy taking coil, inductive power supply, energy storage battery module, wireless charging module, energy management module and patrol UAV with wireless charging function.

1. Introduction
With the rapid development of Chinese economic, “Replace coal and oil with electricity, and clean electricity comes from afar” power substitution strategy, is currently vigorously promoted in China, which can fundamentally adjust China's coal-based energy consumption structure[1]. It’s of great significance to ensure energy security, promote energy conservation and emission reduction, and improve living standards. As electric transmission line is the only way to transmit power, the importance of ensuring its good operation is self-evident, so it is necessary to carry out regular inspection of transmission lines.

As is shown in Figure 1, transmission lines are widely distributed covering a wide area, on account of the complex terrain and harsh natural environment, all kinds of accidents must also be dealt with in a timely manner[2]. With the development of UVA technology, transmission line patrol UVAs are being used more and more widely in various localities of China[3].

![Figure 1. Current Problems in Transmission Lines](image-url)
In order to facilitate the continuous outdoor operation of UVAs, most of the existing field UVAs charging devices use solar cells as the source of electricity, and mostly use contact charging, as shown in Figure 2. The disadvantages of such existing devices are below. First, when encountering bad weather (such as heavy rain or snow, etc.), or even when the surface of solar panels covered with snow and ice, the output power will be greatly affected, decreasing the normal charging efficiency of UVAs. Second, the contact conductive mode increases the difficulty of autonomous landing and charging of UVAs, and requires a shell design with high protection level.

In summary, taking the special operating environment of transmission line patrol UVA into account, that is, transmission line is higher from the ground, and transmission line itself is an inexhaustible source of energy for the UVA, the team proposes a charging and endurance platform for patrol UVA based on inductive power collection of transmission line, and charge the UVA battery through wireless power transmission. It is hoped to reduce the difficulty of autonomous landing charging of inspection UVAs, enhance their field protection conditions, and fundamentally solve problems of inability to continuously inspection because of their short battery life.

2. Research status and development trends at home and abroad

As is shown in Table 1, In China, Huodian Lin, Jie Chen and others proposed the UAV on-board emergency charging power management system to solve the problem of poor endurance of cruise UAV, which greatly expands the endurance and cruise range of UAV[4]. In order to break through the limitations of power technology, Yunzhe Wang, Guoning Xu and others studied the layout of multi charging platforms to provide solutions for UAVs to complete tasks efficiently.

| Aspect                  | Existing problem          | Solution                                      |
|-------------------------|---------------------------|-----------------------------------------------|
| **Power**               | Poor endurance and cruise range | On-board emergency charging power management system |
| **Power**               | Low charging efficiency   | The layout of multi charging platforms        |
| **Flying condition**    | Low lift drag ratio index | Choose large wings                            |
| **Structure**           | Fuselage weight           | Advanced composite materials                  |

In foreign countries, the United States and other countries take the long-range UAV as the research focus, and usually choose the large wing to optimize the lift drag ratio index. The structure is mainly made of advanced composite materials, which can further reduce the fuselage weight; In order to ensure the endurance performance, the energy power system continuously strengthens the reliable performance and energy structure of the equipment[5]. The weight and volume of electronic devices, load systems and power structures are continuously reduced, and the UAV is developing to strong endurance.
3. Overall structure design
The structural diagram of the wireless charging range platform of the inspection UVA based on induction power collection is shown in Figure 3 and contains the following key components: transmission line induction energy coil, induction power supply, energy storage battery module, wireless charging module, energy management module and inspection UVA with wireless charging function.

![Figure 3. The structural diagram of the wireless charging range platform](image)

4. Materials and Methods
Referring to the energy flow path, the specific contents of this project are as follows:

4.1. Transmission line induction power supply research
Inductive power extraction of transmission line is a new type of power supply device which uses the principle of electromagnetic induction to obtain electric energy and realize stable voltage output. The device needs long-term stable and reliable operation, and can adapt to transmission line current changes, with short circuit and impact current self-protection, and the ability to supply reliable power for the later subsystems and circuits.

The inductive power supply of transmission line studied in this project includes these following key technical problems:

4.1.1. Power supply protection circuit
The inductive power supply of the transmission line obtains electric energy from the transmission conductor through the energy collection transformer. Therefore, it is necessary to set the protection circuit of the energy collection power module, which can adjust and limit the electric energy of the input module in real time, absorbing the instantaneous large current caused by lightning and other special conditions, which ensures the safety of the subsequent module.

4.1.2. Power on regulating circuit:
The energy extracted from the transmission conductor by the energy taking transformer is related to the current on the transmission conductor. Generally speaking, the greater the current, the greater the power that the energy taking device can output. The power supply regulating circuit shall automatically adjust the working mode according to the current of the conductor and the power required by the load, including intermittent working mode and continuous working mode. Intermittent working mode: while the current of the transmission line increases to a certain value, the extracted electric energy can start module, but is not enough to support the normal operation of the load, the energy extraction device will be in an intermittent working state; Normal working mode: when the current of the transmission line is large enough and the extracted electric energy can support the load, the energy extraction device
normally outputs the power required by the load, limits the excess energy input to the energy extraction power module, and outputs a stable voltage.

4.2. Research on energy storage battery management technology

4.2.1. Battery working status monitoring: During the working process of the battery, a series of battery related parameters such as battery voltage, temperature, working current, battery power and insulation impedance state are monitored in real time, or the state of the front battery is judged according to these parameters, to carry out corresponding operations to prevent overcharge or over discharge of the battery.

4.2.2. Battery charge and discharge management: During the charging or discharging process of the battery, manage the charging or discharging of the battery according to the current operating state and relevant parameters of the battery state, set the optimal charging or discharging curve of the battery (such as charging current, charging upper limit voltage value, discharge lower limit value, etc.), and realize the protection of battery overcharge, overtemperature, overcurrent, short circuit, etc.

4.2.3. Active equalization of single cell
Transfer the high energy of the monomer to the low energy of the monomer through the form of energy transfer, or supplement the whole group of energy to the lowest battery of the monomer, and use the energy storage link to redistribute the energy between the monomers through this link to realize the balance of the state of the whole group of batteries. All these are shown in Figure 4 in brief.

4.3. Research on autonomous wireless charging technology of patrol UAV

4.3.1. Wireless charging alignment of UAV based on visual guidance
The transmitting coil on the endurance platform and the receiving coil in the UAV are not strictly aligned, and the energy transmission efficiency of the system will be significantly reduced. In order to improve the wireless charging efficiency, the HD cameras installed on the patrol UAV are used to continuously adjust the landing attitude of the UAV and guide the UAV to land by real-time detecting the stop signs on the endurance platform during landing, to achieve accurate wireless charging alignment.

4.3.2. Fast wireless charging technology based on magnetic coupling resonance
The DC power of energy storage battery is converted into high-frequency AC power after high-frequency inverter, and injected into the resonant network composed of parallel resonant capacitor and transmitting coil. Resonance makes the transmitting end circuit and the receiving end circuit work at the same frequency. Resonance occurs between two groups of resonators composed of capacitors and coils and the energy is transmitted through the resonant coil. The maximum power can reach hundreds of watts, and the transmission distance can reach tens of centimeters to several meters.
5. Discussion
At present, wireless charging technology is a hot spot for patrol UAV to improve its endurance capability. Lots of scholars at home and abroad have provided a lot of ideas, but there is little research on wireless charging endurance platform based on inductive power collection. The research on the inductive power supply of the transmission line of the project can make the device have strong adaptability to the current change of the transmission line, and have the self-protection ability of short circuit and impulse current. In the research of energy storage battery management technology, the battery is monitored in real time according to a series of battery related parameters, or the battery state is judged according to these parameters, to realize the protection of battery overcharge, over temperature, over-current and short circuit. At the same time, visual guidance and magnetic coupling resonance are used to realize strict alignment and power transmission of patrol UAV. Therefore, in this project, the wireless charging endurance platform based on inductive power collection has an important impact on the improvement of cruise capability of transmission line patrol UAV.

6. Conclusions
Through the design of induction coil and induction power supply combined with energy storage battery, wireless charging and energy management module, the protection circuit of energy collection power module is set to realize the real-time adjustment and restriction of electric energy of input module, and the energy storage link is used in operation to redistribute the energy between units through this link, the active equalization of single battery is maintained. Based on the principle of inductive power collection, the device is designed to combine various regulation and protection facilities to build a wireless charging and endurance platform, which greatly solves the problems of short dead time and continuous patrol of ordinary patrol UAV.

References
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