Drone Power System Design and Build

ECE445/ME470

Project No. 31

Instructor: Jiahuan Cui

TA: Yanzhao Gong/Haoran Cui/Yanbing Yang

Proposal

Team members：

Bingye He

Zhuoyang Lai

Zikang Liu

Yuyang Tian

1. Introduction

1.1 Title page

- Project title: Design and Construction of an Electric Power System for a Large Drone
- Team number: 31
- Team members: Bingye He/Yuyang Tian/Zikang Liu/Zhuoyang Lai
- TA: Yanzhao Gong
- Date: 2025/3/14
- Course：ECE 445

1.2 Objective and Background

- Goals: The goal of this project is to design and build an electric power system for a large drone. The current challenge in the field of large - drone development is the lack of efficient and reliable power systems that can meet the high - thrust requirements for takeoff and sustained flight. Our project aims to address this issue by creating a power system capable of generating 5kg of thrust at ground level.
- Functions: The designed electric power system will be responsible for converting electrical energy into mechanical thrust to power the large drone. It will manage power distribution, ensure stable voltage supply to different components, and maintain optimal power levels during various flight phases.
- Benefits: For drone manufacturers, this power system offers a more reliable and efficient solution, reducing the risk of power - related failures during flight. End -

users, such as those in the delivery or surveying industries, will benefit from increased flight time, improved payload capacity, and enhanced overall performance of the large drones.

- Features: Our power system will feature high - efficiency power conversion components to minimize energy loss. It will also incorporate advanced control algorithms for real - time power management, making it adaptable to different flight conditions. Additionally, the system will be designed with modularity in mind, allowing for easy component replacement and system upgrades.
- High level requirement:
  - High level requirement 1: motor control must be able to perform higher than 500 W(500W-1000W).
  - High level requirement 2: motor control device must properly connect with motor and motor should properly connect with rotor.
  - High level requirement 3: motor should be strong enough to perform at least 3000 RPM.
  - High level requirement 4: rotor should have the capability to provide 5kg thrust.

2. Design & Requirements

2.1 Block Diagram

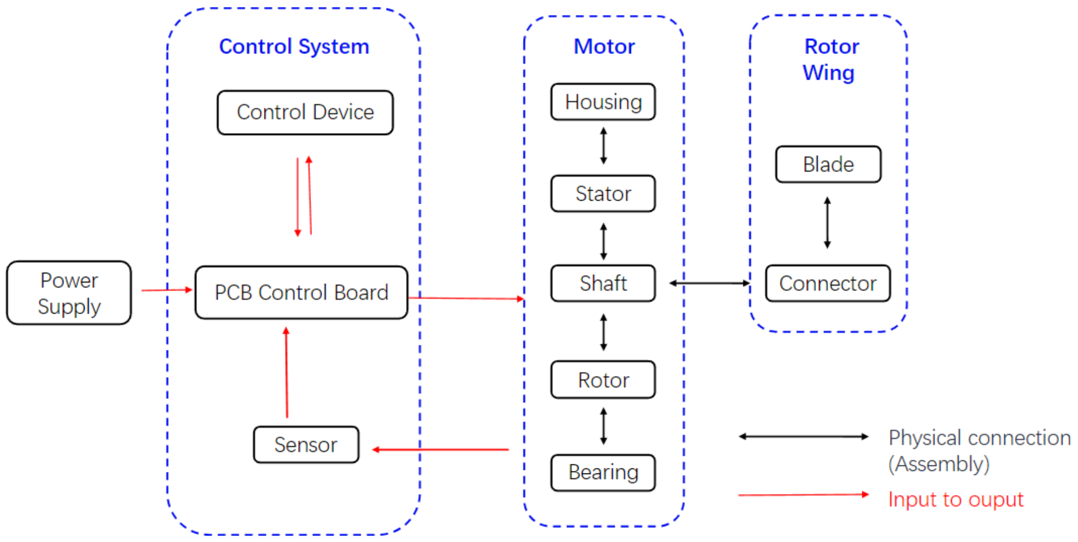

Figure 1: Block Diagram of the Drone Power System

2.2 Block Description & Requirements

2.2.1 manufacturing

This section details the advanced manufacturing processes employed for critical drone components. The rotor is fabricated using the hot carbon fiber press technique—a high-precision composite manufacturing method that begins with the careful layup of carbon fiber pre-preg, pre-impregnated with thermosetting resin, in accordance with specified fiber orientations and stacking sequences. A precision-engineered mold then shapes the rotor, and the assembly is subjected to controlled heat and pressure in a hot press, where the resin cures into a cross-linked matrix while excess resin and entrapped air are eliminated, ensuring optimal fiber alignment, high stiffness, and excellent strength-to-weight characteristics. Simultaneously, specialized metal processing techniques are utilized to manufacture the connectors and the enclosure for the motor and control system, ensuring tight tolerances and reliable structural performance. These integrated processes are crucial to achieving a lightweight, high-performance drone design with robust structural integrity and precise assembly.

Requirements:

Requirement 1: Structural Integrity and Precision

The rotor must exhibit exceptional stiffness and strength, ensured by precise fiber alignment and uniform resin distribution during the hot press process.

Metal components, including connectors and enclosures, must meet stringent dimensional tolerances to secure proper fit and reliable mechanical performance.

Requirement 2: Thermal Stability and Environmental Resistance

All components must maintain consistent performance under varying thermal conditions and environmental stresses such as vibration, humidity, and temperature fluctuations.

Manufacturing processes should mitigate issues related to residual stresses and thermal expansion differences, ensuring long-term stability.

Requirement 3: Process Repeatability and Cost-Effectiveness

Production processes must be highly repeatable, ensuring consistent quality across production batches.

Optimization of manufacturing parameters is essential to reduce material waste and production time, achieving economic feasibility and sustainability.

2.2.2 motor design

2.2.2.1 Electromagnetic Core and Wiring

The electromagnetic core comprises an 18-slot Si-steel stator, 22-pole N52 NdFeB magnets (rotor), and AWG 23 copper windings arranged in a 3-phase configuration. The windings are designed with 8 turns per phase using 3 strands to reduce resistance and enhance thermal conductivity. The electromagnetic core connects to the wiring and housing blocks, forming the fundamental structure of the motor.

Requirements:

Requirement 1: The motor must generate a minimum torque of 2.5 Nm with an efficiency of at least 80%. The motor must have the max rotating speed exceeding 3500 rpm.

Requirement 2: The core dimensions must not exceed 95 mm in diameter and 40 mm in length.

Requirement 3: The wiring must support a high current density of up to 20 A while maintaining power loss below 10%.

Requirement 4: Magnetic field interactions must be optimized to achieve maximum torque density and efficient power conversion. The thermal conductivity of the wiring should ensure that temperature rise remains within acceptable limits (80 °C).

2.2.2.2 Housing and Bearing

An aluminum finned housing is incorporated to dissipate heat generated during motor operation effectively and support the mechanical strength. The bearing uses a 6205 angular contact bearing assembly to ensure smooth rotation, while the enclosure provides durability and vibration resistance.

Requirements:

Requirement 1: The thermal management system must keep the peak operating temperature below **80°C** during continuous operation. Ensure the heat-dissipating efficiency of the housing.

Requirement 2: The housing structure must withstand mechanical stresses while maintaining a compact and lightweight design. Make sure the whole motor is lighter than 2kg.

Requirement 3: The bearings must support rotational speeds up to 3500 RPM with minimal friction losses.

2.2.3 Motor Control

Control system consists of control device, likely laptop, PCB board and hall sensor. control device command a required RPM for motor, and PCB connecting the power source, with its written program, enforce the motor by controlling its input current. Sensor act as an PID control component, monitoring the RPM of motor, and adjusting PCB board output current.

Requirements:

Requirement 1: PCB design for controlling motor and successfully soldering the board

Requirement 2: Finishing connecting the motor and all parts of motoring controlling devices, including communication device (through USB or CAN), and hall sensor as positional encoder.

Requirement 3: Successfully control the motor's RPM through control device

2.2.4 Rotor Design

The rotor wing part consists of two separate blades, and connector which used to combine the blades with the motor system. The rotor wing part act as output component of the motor system.

Requirements:

Requirement 1: Complete the design of the rotor and related connecting parts so that the rotor can provide a thrust of 5 kg or more within the power range permitted by the motor.

Requirement 2: Complete the aerodynamic simulation and mechanical simulation of the rotor to ensure that the designed rotor can meet the required specifications.

Requirement 3: Ensure that the rotor can be assembled on the motor system and is compatible with it, and it should be easy to be processed from carbon fiber.

3. Ethics and Safety

3.1 Ethics

This project involves designing and developing a high-torque-density BLDC motor, rotor structure, blades, and motor control PCB for a large drone capable of generating 5 kg of thrust at ground level. The IEEE Code of Ethics [1] will be strictly adhered to, ensuring that the project maintains high standards of integrity, safety, and societal responsibility throughout its development. The following ethical considerations are applied:

- Ethical Design and Sustainable Development:
    - The BLDC motor is designed for high efficiency (80%) and minimized energy loss through optimized winding configurations, electromagnetic core design, and thermal management systems. This promotes energy-efficient technologies and reduces environmental impact.
    - Material selection for the motor (N52 NdFeB magnets, Si-steel stator, AWG 23 copper windings) and blades (carbon fiber composite) balances performance and sustainability.
- Safety, Health, and Welfare:
    - The system design ensures reliable operation through effective thermal management, maintaining peak temperatures below 80°C.
    - Structural integrity is ensured by using 6205 angular contact bearings and a rigid polycarbonate enclosure, reducing the risk of mechanical failures.
    - Safety concerns are thoroughly addressed to prevent potential hazards during manufacturing, testing, and usage.
- Avoiding Conflicts of Interest:
    - All components are selected based on technical merit and suitability for the project's requirements. The use of the open-source VESC project is appropriately credited, and modifications are transparently documented.
- Acknowledgment of Contributions:
    - Contributions from the VESC project and other resources are properly

credited, and modified firmware is appropriately documented for transparency.

- Technical Competence and Collaboration:
    - The project team actively seeks and offers constructive feedback to improve system performance.
    - Limitations related to material availability, manufacturing precision, and component integration are documented and addressed.
- Respect and Fair Treatment:
    - The project team fosters a collaborative environment where all members are respected and valued. No unethical conduct, harassment, or discrimination will be tolerated.
- Code of Ethics Compliance:
    - All team members are committed to upholding the IEEE Code of Ethics. Any violations of these principles will be addressed transparently and appropriately.

3.2 Safety

Safety is a primary concern throughout the development, testing, and manufacturing of the drone's motor system, rotors, blades, and control circuitry. The following safety aspects are considered:

- Electrical Safety:
    - The motor control PCB operates with high current loads and switching frequencies (up to 120 kHz). Adequate insulation, grounding, and overcurrent

protection are implemented to prevent short circuits, electric shocks, or damage to components.

    - Proper handling procedures for high-voltage components are established, including the use of PPE (Personal Protective Equipment) and safe testing protocols.

- Mechanical Safety:
    - The rotor and housing components are designed to withstand high rotational speeds (up to 3500RPM). Ensuring proper balancing, fastening, and vibration resistance is critical to avoid mechanical failures.
    - The blade design and manufacturing process using hot press carbon fiber ensures structural integrity, minimizing the risk of fracture or separation during operation.
- Thermal Safety:
    - Thermal management is achieved through aluminum finned housing designed to keep temperatures below 80°C. Thermal imaging tests will be conducted to verify performance during high-load operations.
- Lab Safety:
    - All assembly, manufacturing, and testing processes will be conducted in a well-ventilated and properly equipped lab environment.
    - Safety guidelines include using PPE, antistatic wrist straps, and handling high-voltage components with care.
- Safety Plan:

    - A detailed Lab Safety Manual will be created if high-voltage components or hazardous materials are incorporated.
    - Since standard battery systems are used, proper handling, storage, and disposal practices will be followed.
- Justification of Safety Concerns:
    - The project involves standard electrical and mechanical systems, with safety measures designed to ensure a controlled and safe testing environment for developers and end-users.

Reference

1. **IEEE code of ethics** . *IEEE Transactions on Reliability*, vol. R-33, no. 1, pp. 14-14, April 1984. doi: 10.1109/TR.1984.6448267.