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# Design for BLDC Motor Control Systems in Flying Electric Vehicles

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*ABSTRACT*

The choice of control system for a flying electric vehicle/quadcopter is very important, especially for users who have never built or driven a flying electric vehicle. Electrical components which include the flight controller, ESC, battery, BLDC motor and other components have an influence in planning electric flying vehicles. Therefore, a BLDC motor control system is needed so that it can operate according to wishes and needs. The purpose of this research is to find out how the control system wiring diagram works, which includes the flight controller wiring diagram as the main flight control and the Electronic Speed Control (ESC) wiring diagram as the BLDC motor speed controller. The choice of flight controller to operate the electric vehicle flight uses DJI Naza M V2 and electronic speed control uses a flier with a 3s-20s cell count configuration.

**Keywords**: BLDC motor, electric vehicle, control system, motor control design, electric drive system, energy efficiency

## 1. INTRODUCTION

The Modern Transportation era is undergoing a transformative revolution towards the Electrification and Urban Air Mobility (UAM); Along with the increasing awareness of the environmental impact of fossil fuel -based vehicles and demands for more efficient and faster transportation solutions, the development of flying electric vehicles (FEVS) is very urgent, where the motor without brushless direct current/BLDC) has emerged as a dominant choice for power density, efficiency, efficiency, and its reliability is very urgent, where the motorbike is very crucial for Flight stability, efficiency, and safety, with the main challenges in the development of an efficient BLDC control system, tough to disturbance, adaptive to dynamic conditions, and has a high error tolerance. Various studies have been conducted in the last five years to overcome the design challenges of BLDC motor control systems in the application of aerospace and electric vehicles, such as predictive model control exploration (MPC) for BLDC motors on drones that improve transient performance and resistance to parameter variations [1], as well as artificial intelligence -based control applications such as Fuzzy Logic and Artificial Networks (ANN) for efficiency and reduction of Torsi ripples [2]; In addition, research focuses on sophisticated vector control techniques (FOC) for BLDC to achieve high efficiency [4], [5], Sensorless Control Challenges Using Observation Algorithms such as Extended Kalman Filter (EKF) or Sliding Mode Observer (SMO) [6], [7], [8], [9], [10], integration of BLDC control with an energy management system [11] and heat [13], control of redundancy and tolerance of errors in multi-motor propulsion systems [14], [15], [16], adaptive control to overcome the uncertainty of the system [17], as well as the development of control algorithms on DSPS and FPGAS for real time computing [18], [19], [20]. Continuing the trend, the focus has also been given to the development of innovative wide pulse modulation (PWM) strategies for BLDC inverters in order to minimize switching losses and improve current quality [21], optimization of the BLDC motorcycle design itself for optimal power ratios [22], the integration challenges between the motor control system and the flight control architecture as a whole [23]. BLDC in partial failure scenarios [24], the use of co-simulation techniques for system performance validation [25], Electromagnetic Interference Mitigation (EMI) [26], and standardization and certification of electrical propulsion systems for flight applications. Although there is significant progress, substantial research gaps still exist, especially in the context of demanding FEV applications, where most of the existing studies tend to focus on motor performance optimization under ideal conditions and lack of unique challenges such as very varied flight dynamics, extreme error tolerance, or complex interactions between several motorcycles, and lack of solutions to fault-effective partial. This gap underlines the need for a comprehensive design approach to the BLDC control system that is not only efficient but also very tough, intelligent, and fully integrated with FEVS flight dynamics. Therefore, this study aims to design and develop an adaptive BLDC motor control system and fault-tolerant which is specifically optimized for the needs of FEVS, with an emphasis on energy efficiency, flight stability, and operational security, including the development of sophisticated BLDC control algorithms for high energy efficiency at various operating points, design of a resilient control system and adaptive Tolerance of proactive and reactive errors for safe or controlled operations despite failure, and considering aspects of weight optimization and computing power so that it can be implemented practically on the FEVS platform with limited resources, bridging the gap between theory and practical applications in the development of sustainable and safe urban air mobility..

## 2. RESEARCH SIGNIFICANCE

Currently, innovation in electric vehicles is starting to trend, from electric bicycles to electric cars. This research focuses on making a flying electric vehicle using a BLDC motor as the main driver. The aim of making this flying electric vehicle is to determine the effect of load on the stability of a flying electric vehicle, to find out the stability of the vehicle which is influenced by mass variations in BLDC rotation, and the effect of mass on asymmetrical loads on vehicle stability.

The development of electric vehicles at this time helps reduce dependence on limited fuel and the development of new technologies can stimulate growth and progress in various sectors, creating a wider positive impact on technological innovation.

## 3. RESEARCH METHODS

This research uses a design and build method with data collection obtained from descriptive analysis of the results provided by the tool. Before realizing it, first prepare a complete system design so that the research objectives can be achieved.

### 3.1 Materials

The design of the BLDC motor control system for flying electric vehicles uses 4 main components, namely:

1. Flight Controller (DJI NAZA M V2)

As a flight control system and operating mechanism required to control the direction of the aircraft in flight.

2. Electronic Speed Control (Flier 3s-24s)

As an electronic circuit that controls and regulates the speed of an electric motor.

3. BLDC motor (Outrunner)

As a driving force for flying.

4. Battery (LifePo4)

Used to provide the electrical energy required by all components.

### 3.2 Quadcopter Design

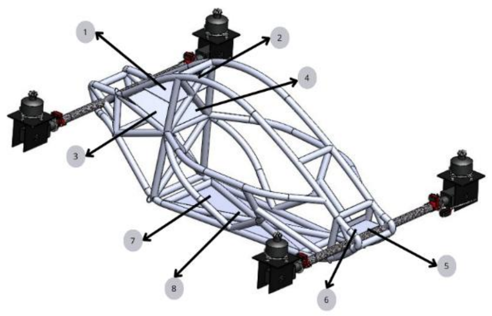


***Figure 1*** *Desain Quadcopter*

Figure 1 explains the quadcopter design and component placement on the quadcopter frame.

1. Flight controller
2. GPS, PMU, LED, and Receiver
3. ESC 3
4. ESC 4
5. ESC 1
6. ESC 2
7. Battery
8. BMS

The flight controller is used as the main flight control which has a very complex program. The flight controller receives signals from the sensors and adjusts the flight controls as needed, with the ESC controlling the speed of the BLDC motor via signals sent from the receiver to the flight controller.

## 4. RESULTS AND DISCUSSION

The entire wiring diagram is created in circuit designer software. This process is carried out to connect the cables/pins in each component to other components so that they can function as desired.

### 4.1 Flight Controller Wiring Design on ESC

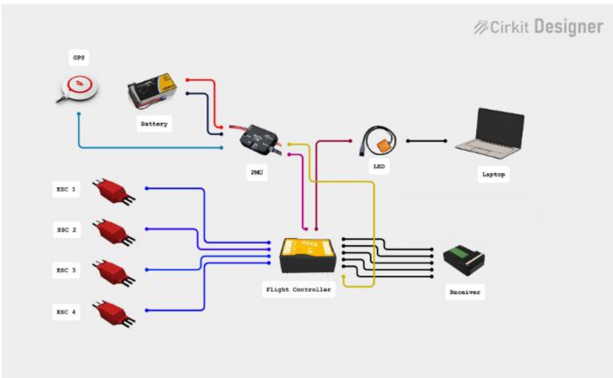


***Figure 2*** *Wiring Flight Controller on ESC*

Figure 2 explains how the flight controller can control the ESC. The flight controller manages and controls the entire electrical system based on input from GPS, receiver,

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battery and altitude. Connects to ESC, PMU, GPS, receiver and LED.

1. GPS

The GPS sensor is connected to the flight control via a PMU (Power Management Unit), the PMU provides location data information from the GPS to the flight control.

2. PMU (Power Management Unit)

The PMU or power management unit receives power from the battery and provides a power supply of 11.1V from the battery to the flight controller.

3. Battery

The battery is connected to a power management unit (PMU), which then distributes power from the battery to other components.

4. LEDs

The LED is a connector connected to the laptop to carry out flight control programs and provide visual indications, for example flight status.

5. Laptops

The laptop is used to program and manage the flight controller via a USB cable connected to the LED.

6. ESC (Electronic Speed Control)

The four ESCs are each connected to the flight controller via pins M1-M4 to control the speed of the BLDC motor based on input from the flight controller.

7. Flight Controller

The flight controller is the main flight control that regulates the quadcopter flight, connected to the GPS, PMU, ESC, and Receiver.

8. Receivers

The receiver is connected to the flight controller and receives signals from the remote control to control the quadcopter.

### 4.2 ESC Wiring Design for BLDC Motors

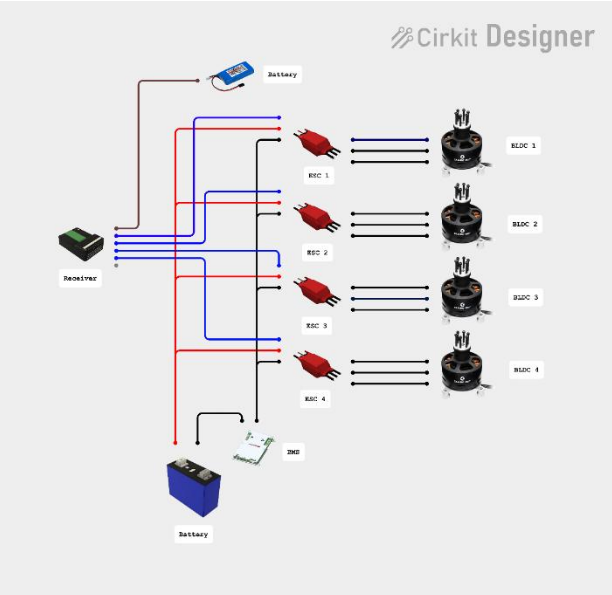


***Figure 3*** *Wiring ESC on BLDC*

The receiver receives signals via the remote control (transmitter) and sends the signals to the ESC. Each BLDC motor uses an ESC which controls its speed, by connecting three phase cables, the ESC receives power from the battery, and the speed control signal through the receiver.

The battery provides power to the ESC via the BMS, managing charging, discharging power from the main battery, and ensuring efficient power management. The BLDC motor is driven by a signal from the ESC. The ESC converts the signal from the receiver and power from the battery into controlling the speed of the BLDC motor.

The following is an explanation of the function and wiring in Figure 3 above:

1. Receiver

The receiver receives a signal from the remote control then sends the signal to the ESC to control the speed of the BLDC motor. The signal cable from the ESC is connected to the CH1-CH4 pins of the receiver.

2. ESC

Four ESCs each connected to the BLDC motor by connecting 3 phase cables (U, V, W) to the BLDC motor

3. BLDC motors

Four BLDC motors are connected to each ESC with three phase cables that provide phase signals to drive the BLDC motors.

4. BMS

BMS (Battery Management System) is connected to the main battery to manage the charging and use of battery current, to ensure the battery does not overcharge or overdischarge.

5. Battery

The main battery provides power supply for the entire system, namely the BLDC motor, BMS, and ESC.

The entire wiring diagram explains the flow of power and control signals from the battery and receiver to the ESC and BLDC, forming an ESC control system on the BLDC motor to control the speed and direction of rotation of the motor.

#### 4.2.1 ESC Flier Program

This computer software for flier ESC is intended for programming electronic speed control (ESC) components where there are several things that need to be adjusted before use. At the top left, you can see the COM port which is used to connect the PC/Laptop to the ESC, and the ESC Type flier has a drop-down menu to select the ESC type from the flier, the type selected is Air 3-24s. It can be seen in figure 4

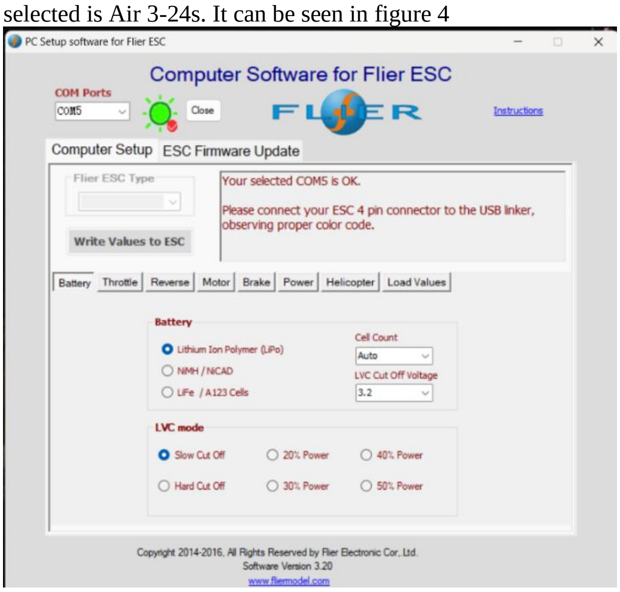


***Figure 4*** *Flier Program*

### 4.2.2 Program DJI Naza M V2

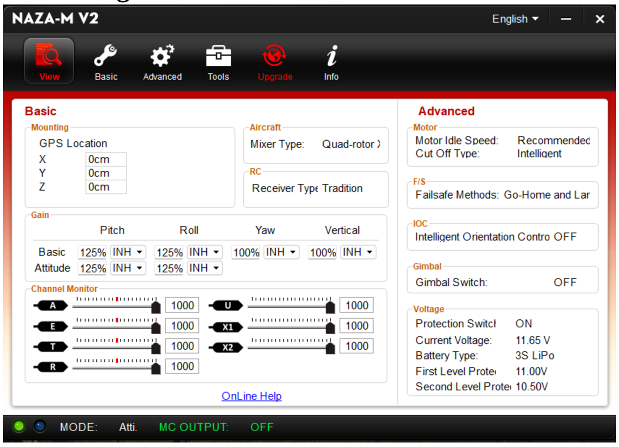


***Figure 5*** *DJI NAZA M V2 Program*

Figure 5 above shows the interface display of the NAZA-M V2 flight control system. Below are details of the sections displayed.

1. Basic

**Mounting**

| GPS Location | | |
|---|---|---|
| X | Y | Z |
| 0 | 0 | 0 |

**Aircraft**

Mixer Type: Quad-rotor

**RC (Remote control)**

Receiver type: Tradition

**Gain**

| | Basic | Altitude |
|---|---|---|
| Pitch | 125% | 125% |
| Roll | 125% | 125% |
| Yaw | 100% | - |
| Vertical | 100% | - |

Channel Monitor

A 1000

E 1000

T 1000

R 1000

X1 1000

X2 1000

U 1000

2. Advanced

**Motor**

Motor Idle Speed: Recommended

Cut Off Type:Intelligent

**F/S (Failsafe)**

Failsafe Methods: Go-Home and Landing

**IOC**

Intelligent Orientation Control: OFF

**Gimbal**

Gimbal Switch: OFF

**Voltage**

Protection Switch: ON

Current Voltage: 11.65V

Battery Type: 3S LiPo

First Level Protection: 11.00V

Second Level Protection: 10.50V

This interface program is used to set various parameters and settings of the NAZA-M V2 flight control system.

## 5. CONCLUSION

Based on the results of the planning and discussion from the previous chapter, the planning of the BLDC motor control system for flying electric vehicles can be concluded as follows:

1. Control system planning for the BLDC motor of a flying electric vehicle was successfully made by making adjustments to the BLDC motor used.
2. The electrical wiring diagram for the flight controller can be seen in Figure 4.1
3. The electronic speed control wiring diagram can be seen in Figure 4.2
4. The flight control system or flight controller uses DJI NAZA M V2.
5. Speed controller/electronic speed control uses a flier programmable ESC with a cell count configuration of 3-24s.
6. Program variations on the ESC flier have an influence on the BLDC motor, such as the battery which can be adjusted according to the battery used, variations in the throttle, changes in rotation on the BLDC motor, setting the motor angle to a certain value, adjusting the motor brake, selecting the starting power when the motor is first started, and selecting the RPM mode on the BLDC motor.
7. The DJI NAZA M V2 flight control system has a configuration to operate the quadcopter with specific settings for various parameters.

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## 7. AUTHOR CONTRIBUTIONS

Conception and design: Muhammad Nurus Syamsi
Methodology: Muhammad Nurus Syamsi
Data acquisition: Muhammad Nurus Syamsi
Analysis and interpretation of data: Sugeng Hadi Susilo
Writing publication: Muhammad Nurus Syamsi
Approval of final publication: Muhammad Nurus Syamsi
Resources, technical and material supports: Muhammad Nurus Syamsi
Supervision: Sugeng Hadi Susilo

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