P Series High-Voltage Propulsion System High-Voltage Power Distribution Solution Design and Hardware Selection Guide V1.1

1. Background

The P Series high-voltage propulsion systems are applicable to 400V/800V battery voltage platforms. The ESCs (Electronic Speed Controllers) contain large-capacity internal capacitors (ranging from several hundred µF to several thousand µF) and do not have a built-in high-voltage pre-charge function. Therefore, when powering on the system, high voltage must be applied via an external pre-charge circuit. **Directly connecting the high-voltage battery is strictly prohibited**—doing so is equivalent to connecting the battery to a capacitive load, which will cause an instantaneous short circuit on the ESC bus, generating extremely high inrush current. This may not only produce electrical sparks during cable contact but also severely affect the service life of the product.

Based on the above, the P Series high-voltage propulsion system must be used with a **High-Voltage Power Distribution Unit (PDU)**, and a comprehensive pre-charge circuit and power distribution scheme must be designed within the PDU. This document aims to assist you in completing the detailed design and hardware selection of the high-voltage PDU to ensure safe and stable product operation.

2. High-Voltage Power Distribution Solution Design

Considering differences in application scenarios, power configurations, thrust redundancy requirements, and weight limitations, this document provides two high-voltage power distribution solutions for customers to select and reference based on their actual needs.

2.1 Distribution Solution I

2.1.1 Solution Description

A single set of pre-charge circuit is provided, which supplies pre-charge to all ESCs after aggregation.

Advantages: Simple distribution components, small PDU size, and light weight.

Disadvantages: When a short circuit occurs on a single ESC bus or an open circuit occurs on the main positive circuit, the entire system will lose all power. Common-cause failures will result in the loss of multi-axis & multi-propeller power redundancy.

2.1.2 Schematic Diagram

Taking a 4-axis, 4-propeller configuration using 400V platform propulsion system (P50M/P65M/P65V) with 4 ESCs as an example, the PDU power distribution schematic is shown in Figure 1:

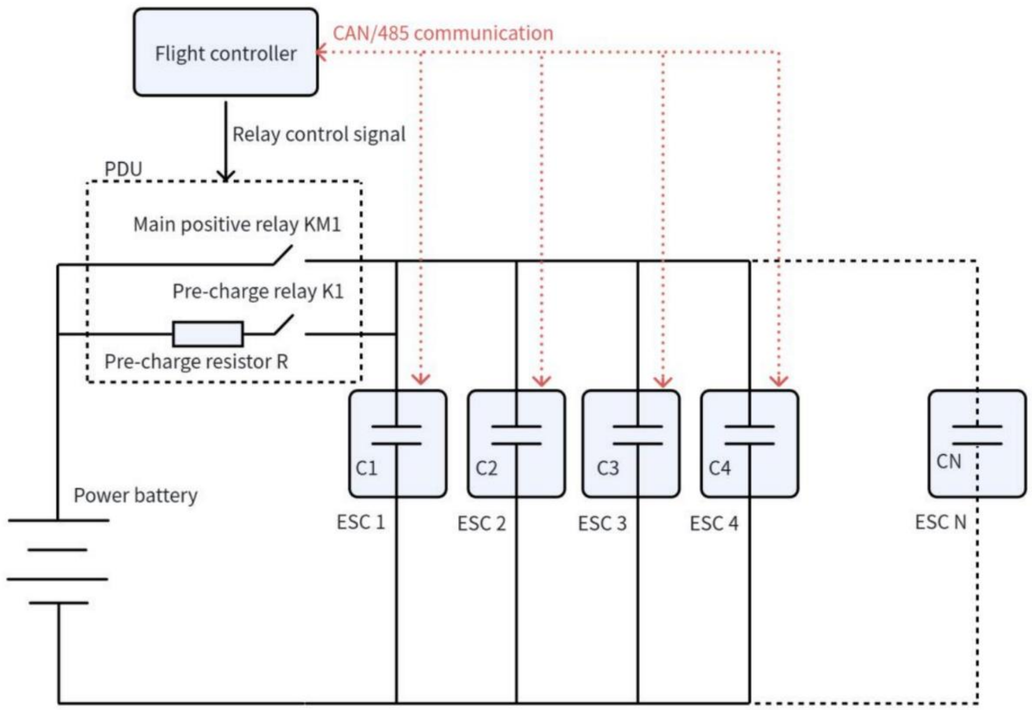

Figure 1 Solution I (4-axis, 4-propeller) PDU Distribution Schematic

The high-voltage power-on logic is shown in Figure 2:

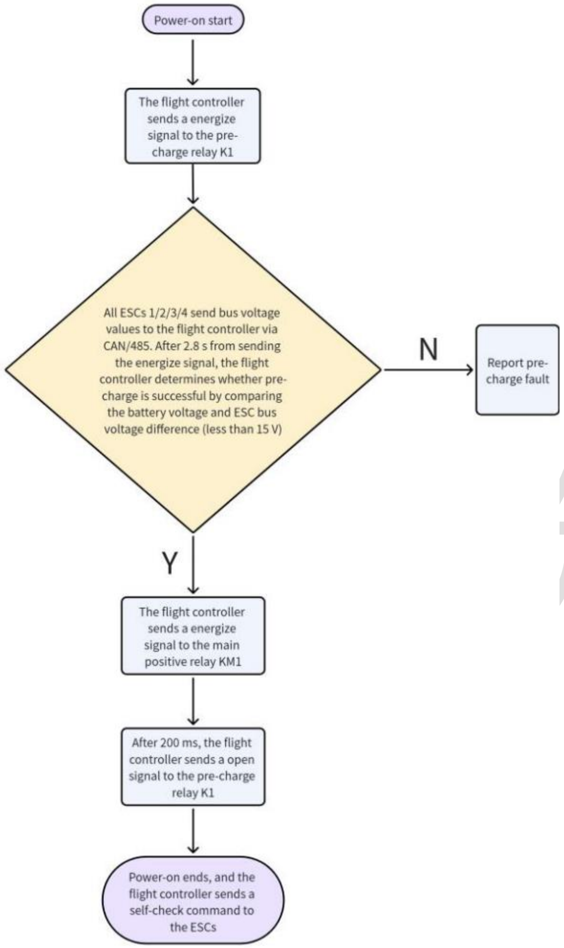

Figure 2 Solution I high-voltage power-on logic diagram

2.1.3 Special Notes

1) The 24 V power supply used for the drive coils of relay must be electrically isolated from the high-voltage DC bus;

2) After successful high-voltage power-on, the ESCs must receive commands from the flight controller before performing self-check; otherwise, the pre-charge resistor may be damaged.

Note: It is recommended that customers use a 60 Ω resistor for the CAN bus termination resistor.

2.2 Distribution Solution II

2.2.1 Solution Description

Each ESC is equipped with an independent pre-charge circuit to achieve independent pre-charge.

Advantages: When a short circuit occurs on a single ESC bus or an open circuit occurs on the main positive circuit, the fault point can be disconnected via the main positive contactor. The issue can be reported to the flight controller to redistribute power, ensuring the effectiveness of the multi-axis & multi-propeller power redundancy design and avoiding catastrophic failures. Additionally, with independent pre-charge for each ESC, the pre-charge time can be reduced to approximately 1 s.

Disadvantages: A larger number of distribution components are required. Compared with Solution I, the PDU is larger in size and heavier in weight.

2.2.2 Schematic Diagram

Taking a 4-axis, 4-propeller configuration with 4 ESCs as an example, the PDU power distribution schematic is shown in Figure 3:

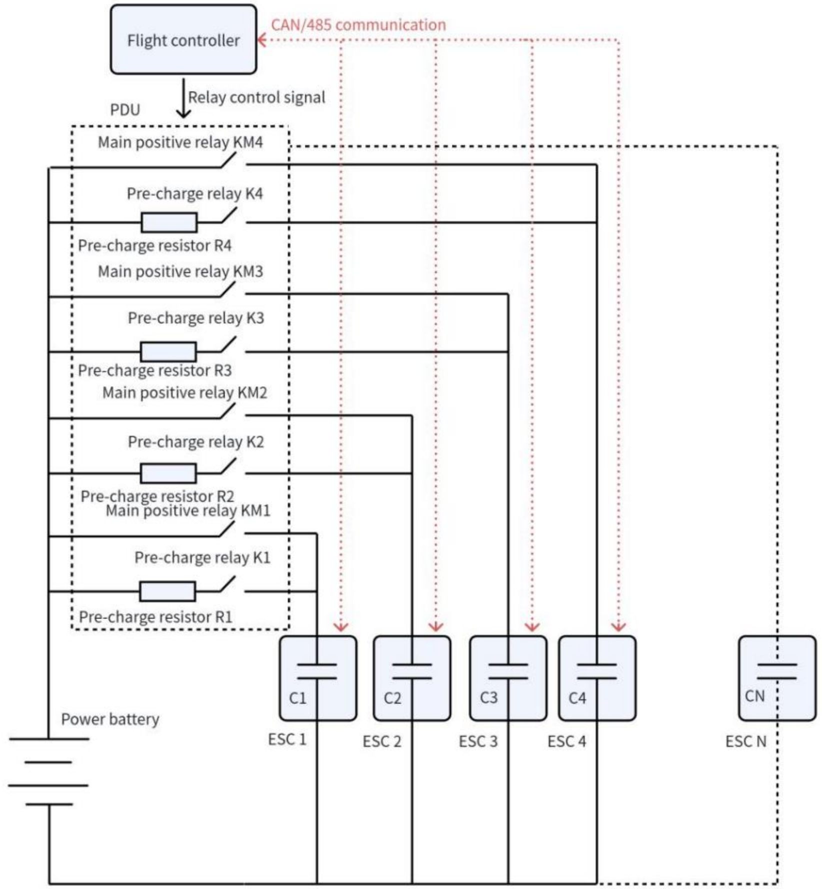

Figure 3 Solution II (4-axis 4-propeller) PDU Distribution Schematic

The high-voltage power-on logic is shown in Figure 4:

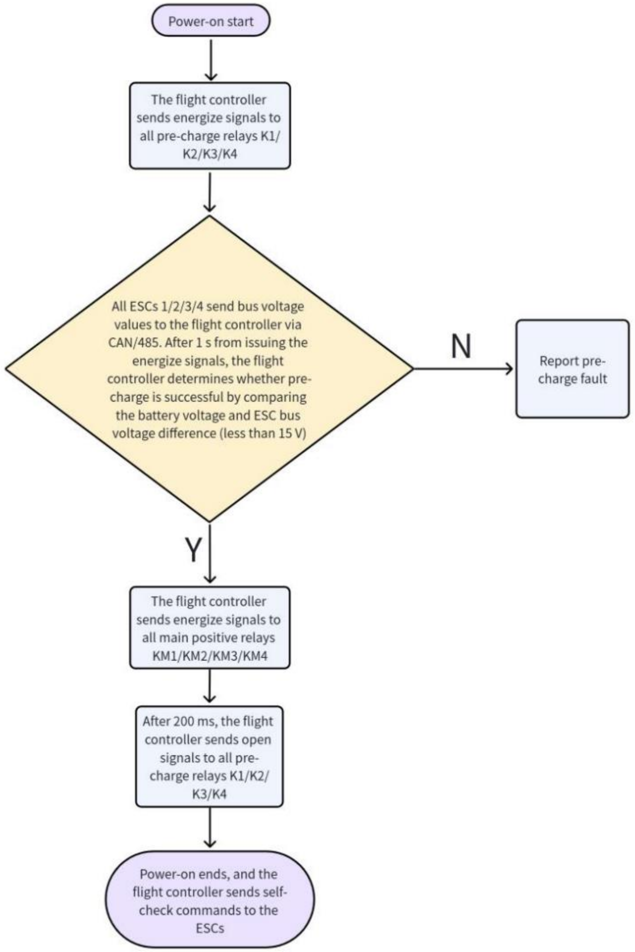

Figure 4 Solution II High-Voltage Power-On Logic Diagram

2.2.3 Special Notes

1) The 24 V power supply used for the drive coils of relay must be electrically isolated from the high-voltage DC bus;

2) After successful high-voltage power-on, the ESCs must receive commands from the flight controller before performing self-check; otherwise, the pre-charge resistor may be damaged.

Note: It is recommended that customers use a 60 Ω resistor for the CAN bus termination resistor.

3. Hardware Selection Guide and Calculation Examples

3.1 Key calculation formulas

1. Pre-charge Resistance Rpre (Ω):

$$R_{pre} = -T_{pr}/(C_{bus} \times \ln(1 - k))$$

C_{bus} is the bus capacitance (F);

k is the ratio of target pre-charge voltage to battery voltage;

T_{pr} is the target pre-charge time (s);

2. Pre-charge Resistor Heat Dissipation E_{re} (J):

$$E_{re} = 0.5 * C_{bus} * V_{bus} * V_{bus} * (2k - k * k)$$

V_{bus} is the battery voltage;

3. Pre-charge Resistor Peak Power P_{peak} (W):

$$P_{peak} = V_{bus} * V_{bus} / R_{pre}$$

4. Pre-charge Resistor Average Power P_{avg} (W):

$$P_{avg} = E_{re} / T_{pr}$$

5. Pre-charge Peak Current I_{pk} (A):

$$I_{pk} = V_{bus} / R_{pre}$$

3.2 Solution I: Component Selection and Calculation

The following calculations are based on a maximum battery voltage of 450 V, a pre-charge target value of 98% (k = 0.98), and a pre-charge time of 2.8 s.

3.2.1 Component Selection Calculation Parameter Table

Known conditions: Maximum battery voltage for 400V platform propulsion system is 450 V, the minimum operating voltage required for rated power is 315 V, the minimum operating voltage required for peak power is 336 V. And for a single ESC, the rated input current is 30 A, the peak input current is 100 A (5 s). According to the calculation formulas in Section 3.1, the PDU component selection calculation parameters for different power configurations in Solution 1 are shown in Table 1.

Table 1 Component Selection Calculation Parameters for Solution I

Pre-charge Configuration	Hobbywing Product Model	Battery Voltage/ V	**Bus Capacitance /F**	**Pre-charge Resistance/ Ω**	**Pre-charge Resistor Heat Dissipation/ J**	**Pre-charge Resistor Peak Power/W**	**Pre-charge Resistor Average Power/W**	**Pre-charge Peak Current/A**	**Bus Rated Current/ A**	**Bus Peak Current/ A (5 s)**
4-axis & 4-propeller	P50M/P65M/P65V (400V)	450	1.984×10^{-3}	360.76	200.8	561.32	71.71	1.25	120	400
6-axis & 6-propeller		450	2.976×10^{-3}	240.5	301.2	841.98	107.57	1.87	180	600
4-axis & 8-propeller		450	3.968×10^{-3}	180.38	401.6	1122.64	143.43	2.49	240	800
6-axis & 12-propeller		450	5.952×10^{-3}	120.25	602.4	1683.96	215.14	3.74	360	1200
4-axis & 4-propeller	P85M(400V)	450	1.984×10^{-3}	360.76	200.8	561.32	71.71	1.25	188	480
6-axis & 6-propeller		450	2.976×10^{-3}	240.5	301.2	841.98	107.57	1.87	282	720
4-axis & 8-propeller		450	3.968×10^{-3}	180.38	401.6	1122.64	143.43	2.49	376	960
6-axis & 12-propeller		450	5.952×10^{-3}	120.25	602.4	1683.96	215.14	3.74	564	1440

4-axis & 8-propeller	P115M(800V)	850	0.24×10^{-3}	2982.26	86.67	242.27	30.95	0.29	120	360
6-axis & 12-propeller		850	0.36×10^{-3}	1988.17	130	363.4	46.43	0.43	180	540

3.2.2 Recommended Hardware Selection Parameters

Pre-charge Resistor Requirements: Impact resistant, high reliability. Aluminum-housed wirewound power resistors are recommended, with ±1% accuracy, ±100 ppm/°C temperature coefficient, and 2500V withstand voltage. Based on engineering experience, the rated power of the resistor should be 1/4 to 1/3 of the peak power. Considering common commercially available market components, the final selection result of the pre-charge resistors are shown in Table 2.

For different power configurations in Distribution Solution 1, the pre-charge peak current is calculated in Table 1 to be 1.25~3.74A, with a maximum battery voltage of 450 V. To ensure reliability, it is recommended to use automotive-grade relays that are widely adopted and proven in mass production (featuring excellent vibration resistance and electrical life). Based on general component specifications, the selected pre-charge relays should meet the following parameters: **Rated load current 20 A; breaking current ≥30 A; load voltage ≥450 VDC (for 400V platform propulsion system) or load voltage ≥1000 VDC (for 800V platform propulsion system); coil voltage 24 V. The same model parameters are compatible with all application scenarios.**

For different configurations in Distribution Solution I, the bus rated current and peak current vary significantly, with a maximum battery voltage of 450 V. As the main relay is a critical path for power during flight, to avoid single-point failure, the selection must focus on performance parameters such as operating temperature, electrical life, maximum breaking current, maximum breaking voltage, rated load current, rated load voltage, dielectric withstand voltage, with sufficient margins. It is recommended to select automotive-grade relays widely used in mass production (with excellent vibration resistance and electrical performance). The general requirements for the main relay are as follows: **Operating temperature range ≥ -40°C to +85°C; electrical life ≥1000 cycles at 450 VDC rated load; maximum breaking voltage ≥1000 VDC; rated load voltage ≥750 VDC (for 400V platform propulsion system), or rated load voltage ≥1000 VDC (for 800V platform propulsion system); dielectric withstand voltage (between contacts / between contacts and coil) ≥3000 VAC for 1 min; coil voltage 24 V. Considering the harsh vibration environment of UAVs, for relays with a rated current endurance of 600 A or less, the weight shall not exceed 500 g. Otherwise, there is a risk of damage due to long-term vibration.** Based on the bus current calculation results in Table 1, the final selection results of the main relay are shown in Table 2.

Table 2 Component Selection Parameters for Solution I

Pre-charge Configuration	Hobbywing Product Model	**Pre-charge Resistor**			**Pre-charge Relay**			**Main Relay**			
		Resistance/Ω	**Rated Power/W**	**Withstand voltage/V**	**Rated Load Current/A**	**Breaking Current/A**	**Load Voltage/VDC**	**Rated Load Current/A**	**Maximum Breaking Current/A**	**Current Withstand/A**	**Selected Relay Weight/g**

4-axis & 4-propeller	P50M/P65M/P65V（400V）	360	200	2500	20	≥30	≥450	200	2000	900A : 10s	<500
6-axis & 6-propeller		240	300					300		1000A : 25s	
4-axis & 8-propeller		180	350					600		1500A : 60s	
6-axis & 12-propeller		120	500					600		1500A : 60s	
4-axis & 4-propeller	P85M（400V）	360	200					300		1000A:25S	
6-axis & 6-propeller		240	300					600		1500A:60s	
4-axis & 8-propeller		180	350					600		1500A:60s	
6-axis & 12-propeller		120	500					800		3000A:30s	<1100
4-axis & 8-propeller	P115M(800V)	2900	100				≥1000	200		900A:10S	<500
6-axis & 12-propeller		1900	150					300		1000A:25S	

3.3 Solution II: Component Selection and Calculation

The following calculations are based on parameters of a single ESC: Maximum battery voltage 450 V; bus capacitance of a single ESC is

4.96×10^{-4} F; pre-charge target value 98% (k = 0.98); pre-charge time 0.9 s.

3.3.1 Component Selection Calculation Parameter Table (Single ESC)

Known conditions: Maximum battery voltage is 450 V; the minimum operating voltage required for rated power is 315 V; the minimum operating voltage required for peak power is 336 V; the rated input current of a single ESC is 30 A; and the peak input current is 100 A (5 s). Based on the above formulas and known conditions, the PDU component selection calculation parameters for all power configurations in Solution II are identical, as shown in Table 3.

Table 3 Component Selection Calculation Parameters for Solution II

Pre-charge Configuration	roducts Model	Pre-charge Resistance/Ω	Pre-charge Resistor Heat Dissipation/J	Pre-charge Resistor Peak Power/W	Pre-charge Resistor Average Power/W	Pre-charge Peak Current/A	Bus Rated Current/A	Bus Peak Current/A (5 s)
Single ESC	P50M/P65M/P65V（400V）	463.83	50.2	436.58	55.78	0.97	30	100
Single ESC	P85M（400V）	463.83	50.2	436.58	55.78	0.97	47	120
Single ESC	P115M（800V）	7668.67	10.83	94.21	12.04	0.11	15	45

3.3.2 Recommended Hardware Selection Parameters (Single ESC)

Pre-charge Resistor Requirements are consistent with Solution 1: Impact resistant, high reliability. Aluminum-housed wirewound power resistors are recommended, with ±1% accuracy, ±100 ppm/°C temperature coefficient, and 2500V withstand voltage. Based on engineering experience, the rated power of the resistor should be 1/4 to 1/3 of the peak power. Considering common commercially available market components, the final selection result of the pre-charge resistors are shown in Table 4.

For different power configurations in Distribution Solution 2, based on the calculation results in Table 3, the pre-charge peak current is 0.97 A, with a maximum battery voltage of 450 V. To ensure reliability, it is recommended to use automotive-grade relays that are widely adopted and proven in mass production (featuring excellent vibration resistance and electrical life). Based on general component specifications, the selected pre-charge relays should uniformly meet the following parameters: **Rated load current 20 A; breaking current ≥30 A; load voltage ≥450 VDC (for 400V platform propulsion system), or rated load voltage ≥1000 VDC (for 800V platform propulsion system); coil voltage 24 V. The same model parameters are compatible with all application scenarios.**

For different configurations in Distribution Solution II,the same model and specification of main relay can be used. The selection must focus on performance parameters such as operating temperature, electrical life, maximum breaking current, maximum breaking voltage, rated load current, rated load voltage, dielectric withstand voltage, with sufficient margins. It is recommended to select automotive-grade relays widely used in mass production (with excellent vibration resistance and electrical performance). The general requirements for the main relay are consistent with those in Solution I: **Operating temperature range ≥ -40°C to +85°C; electrical life ≥1000 cycles at 450 VDC rated load; maximum breaking voltage ≥1000 VDC; rated load voltage ≥750 VDC (for 400V platform propulsion system), or rated load voltage ≥1000 VDC (for 800V platform propulsion system); dielectric withstand voltage (between contacts/between contacts and coil) ≥3000 VAC for 1 min; coil voltage 24 V.** Considering the harsh vibration environment of UAVs, the relay weight must not exceed 500 g; otherwise, there is a risk of **damage due to long-term vibration**. Based on the bus current calculation results in Table 3, the final selection results of the main relay are shown in Table 4.

Table 4 Component Selection Parameters for Solution II

Pre-charge Configuration	Hobbywing Product Model	**Pre-charge Resistor**			**Pre-charge Relay**			**Main Relay**			
		Resistance/Ω	**Rated Power/W**	**Withstand voltage/V**	**Rated Load Current/A**	**Breaking Current/A**	**Load Voltage/VDC**	**Rated Load Current/A**	**Maximum Breaking Current/A**	**Current Withstand/A**	**Selected Relay Weight/g**
Single ESC	P50M/P65M/P65V/P85M（400V）	470	150	2500	20	≥30	≥450	100	1000	900A : 4s	<500
Single ESC	P115M（800V）	7600	40	2500			⩾1000	100	1000	900A : 4s	<500

Considering various factors such as different power configurations, reliability requirements, safety indicators, size and weight limitations, PDU complexity, and procurement convenience, the following recommendations are made for P Series high-voltage propulsion system PDU selection:

1) For 4-axis, 4-propeller application scenarios: As there is no power redundancy in the system, Distribution Solution I is preferred. This solution features simple PDU circuitry, compact size, and light weight;

2) For 6-axis 6-propeller, 4-axis 8-propeller, and 6-axis 12-propeller application scenarios: As the system is designed with power redundancy, Distribution Solution II is preferred. This solution ensures the independence of power redundancy, avoids catastrophic failures caused by common-cause failures, and offers a high degree of component standardization within the PDU for convenient procurement. Meanwhile, independent pre-charge enables shorter power-on time.

Important Note

The hardware parameters and selection solutions provided in this guide are only applicable to P50M/P65M/P65V/P85M, and P115M propulsion systems that have undergone our company's rigorous internal testing and validation. The parameters of power distribution solution for other models of propulsion systems are for reference only, and customers must conduct thorough verification before use.