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Anti-Arcing DC Circuit Breaker for High Payload Drone Application

Nabil Fikri Rosli[1], **Mohd Aifaa Mohd Ariff**[1]*

[1]Faculty of Electrical and Electronic Engineering,
Universiti Tun Hussein Onn Malaysia, Batu Pahat, 86400, MALAYSIA

*Corresponding Author Designation

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Abstract: This project discusses the development of an anti-arcing DC circuit breaker for high-payload drone applications. For a heavy-lift drone, there is a common issue of arcing and high current during the operation because the circuit is highly capacitive. In order to address this issue, the anti-arcing DC circuit breaker is proposed in this project. First, the circuit breaker is designed and simulated using the MULTISIM software. Then, the performance of the circuit breaker is evaluated under various operating conditions. Next, the printed circuit board of the circuit breaker is designed using the ULTIBOARD software. From the simulation, it is observed that the circuit breaker is able to limit the inrush current to the speed controller circuit during the circuit-making process. On the other hand, the circuit is able to withstand the high current flow during normal operating conditions. The result implies that the proposed anti-arcing DC circuit breaker is able to reduce the arcing during the circuit-making process while withstanding a huge current flow during normal operating conditions. The performance of the proposed circuit breaker is crucial for a heavy-lift drone to ensure that the operator does not expose to an arc during operation.

Keywords: Arcing, Inrush Current, High Payload Drone, Printed Circuit Board.

1. Introduction

The aircraft industry is now growing very fast, not only to carry passengers but some are also designed to transport goods in large quantities. In particular, the development of drones which are now widely used in activities to carry heavy loads. Focusing on the powerplant and control of the drone, the system architecture consists of brushless DC (BLDC) motors, electronic speed controllers (ESC), autopilot systems control, and a propeller. These components are vital to the operation in order to provide sufficient thrust to lift the drone. From the operational perspective, the making and breaking of the connection between the battery and the ESC are required frequently, especially during the development phase of the drone. The development of high-powered circuit breakers is mainly focused on AC power applications [1]. However, the development of DC circuit breaker is just recently gained attention from the researcher due to the implementation of DC links for grid control purposes [2].

**Corresponding author: aifaa@uthm.edu.my*
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Typically, a heavy-lift drone is driven by a high-power propulsion system to provide the thrust to lift the aircraft. During the development and operation of the aircraft, the aircraft will undergo countless energization and de-energization processes. There is a safety issue during the energization process, where typically there is an arc occurs when the operator makes the connection between the battery and the ESC. The ESC is typically a capacitive circuit. Thus, there will be a significant inrush current when the operator makes the connection. Eventually, the arc will degrade the quality of the connector and increase the power transmission loss in the system [3]. During the flight, the current flowing through this path is relatively huge as compared to surveillance drone applications. In the heavy-lift drone application, the current can go up to 2kA. In addition, the heavy-lift drone application is weight-sensitive. Thus, any subsystem to be considered in the aircraft has to be as light as possible to maximize the performance of the drone.

This project is aimed to design and develop the anti-arcing DC circuit breaker for high payload drone applications. The circuit needs to first before developing the hardware of the anti-arcing DC circuit breaker which is PCB assembled with selected components.

2. Materials and Methods

Figure 1 shows the flowchart of the project. The development process starts with the design specification which specifies the value and parameter of the components that will be used. Next, the project progress is to run the simulation to show the result and verify the operation of the system. If the results do not fulfill the desired parameter of the result, each component will be replaced by the other component that complies with the circuit.

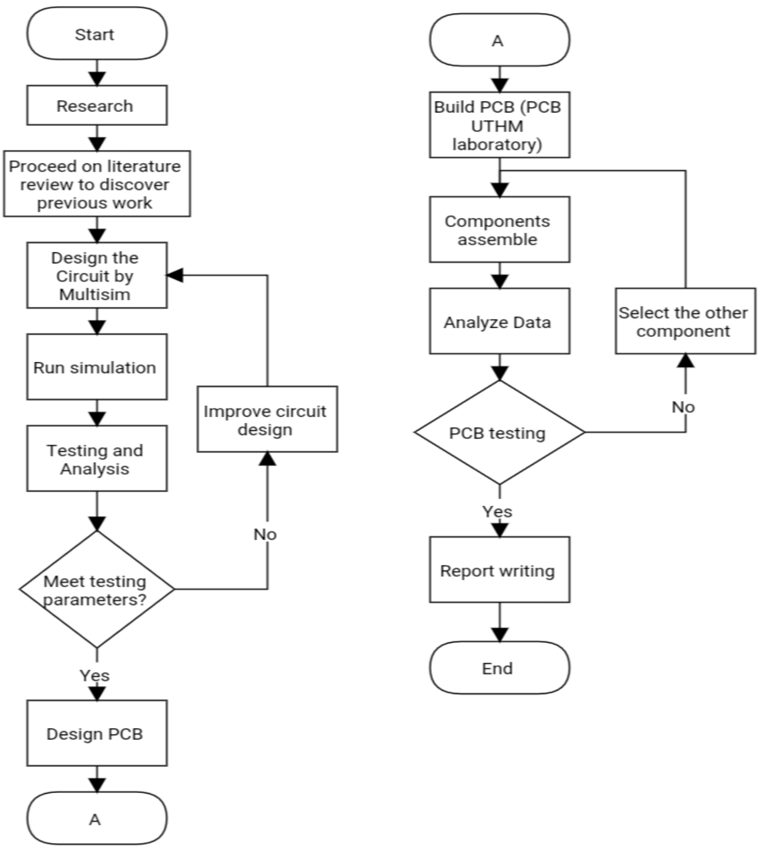

Figure 1: Flowchart of the project

The development of the anti-arcing DC circuit breaker requires a circuit to connect with correct resistor, capacitors, MOSFET and Zener diode as shown in Figure 2. The circuit had been designed by using NI Multisim and NI Ultiboard for designing the PCB design. All these components will be placed in the PCB design. The anti-arcing circuit is designed with components and its parameters shown in Table 1 with the PCB design in Figure 3.

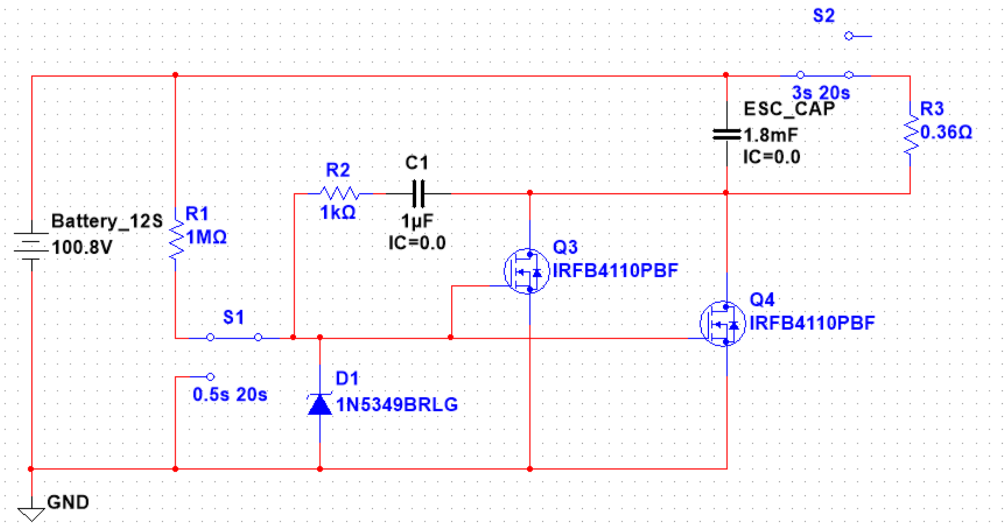

Figure 2: Design of anti-arcing DC circuit breaker

Table 1: Components parameters for designing the circuit

Item	Label	Value
Resistor	R1	1MΩ
Resistor	R2	1kΩ
Capacitor	C1	1uF
Zener diode	D1	1N5348BRLG
MOSFET	Q3, Q4	IRFB4110PBF
Capacitor	ESC_CAP	1.8mF
Switch	S1, S2	

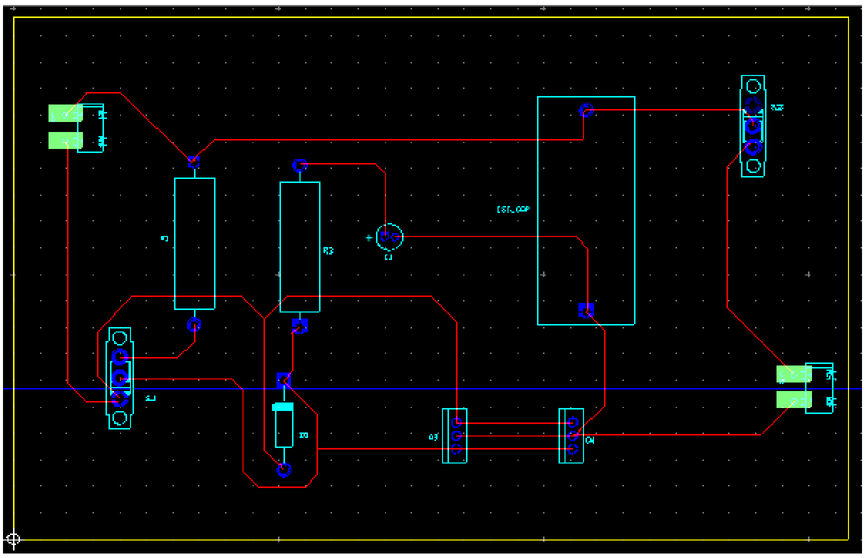

Figure 3: PCB design in NI Ultiboard

The experiment setup is shown in Figure 4. The anti-arcing DC circuit breaker will be connected between the DC source and the electronic speed controller (ESC). Firstly, connect two pieces of the 12S LiPo battery (50.4V) in series to obtain 100.8V of DC source. Then, connect the ESC output to the BLDC motor and also its controller. Power up the controller with a 3S LiPo battery (12.6V). After completing all the connections, the PCB design needs to be to the DC source for testing.

Figure 4: PCB testing setup

3. Results and Discussion

The results of the designed circuit are obtained from the simulation by using the NI Multisim. All the result above shows the reading of voltage and current, for each component in the circuit. By obtaining the result from this simulation, the analysis of the designed circuit will be made. The analysis of the result will show either the components that need to be replaced or changing the design of the circuit. From the DC source which is supply 100.8V to the circuit flow through the 1MΩ of a resistor. If the switch (S1) is set on t_off, the supply will pass through the circuit to the ESC_CAP. Here, the voltage will slowly charge the capacitor until it reaches 100.8V from the supply. At first, the capacitor has 0 charge, which is it needs to store the voltage from the supply. Once the capacitor had been fully charged, the switch (S1) will be set to t_on. This is because, during the operation of the circuit, the 1MΩ resistor will not be used. It will be affecting the performance of the circuit. Table 2 depicts the result of the voltage and current passing through each component after 5 seconds of the operation.

Table 2: Result for voltage and current after 5 seconds of the operation

Item	Parameter	Voltage (V)	Current (A)
Resistor	1MΩ	15	0
Resistor and capacitor	1kΩ & 1uF	15	0
Zener diode	-	12	0
MOSFET	-	20	150
Capacitor ESC	Data Point 4	100	0

The resistor of 1MΩ is the one of important component to ensure this circuit be able to operate as desired. The simulation proves that the DC supply of 100.8V had been decreased to 50.0V after passing through the resistor. This is because the resistance causes the voltage to drop from the supply. The electrons lose energy as they interact with electrons in the conducting material as they pass through the resistor. As energy is given up by the material, it gains thermal energy and thus rises in temperature. Moving electrons lose potential energy, resulting in a voltage drop.

Figure 5 shows the result for the voltage and current reading at MOSFET. The graph of a probe for voltage is reduced at 0.5s. It shows that the reading of voltage slowly decreases. The other probe shows that the voltage for the ESC capacitor slowly increases which is it starts to build up. The current build-up after 3s of the operation.

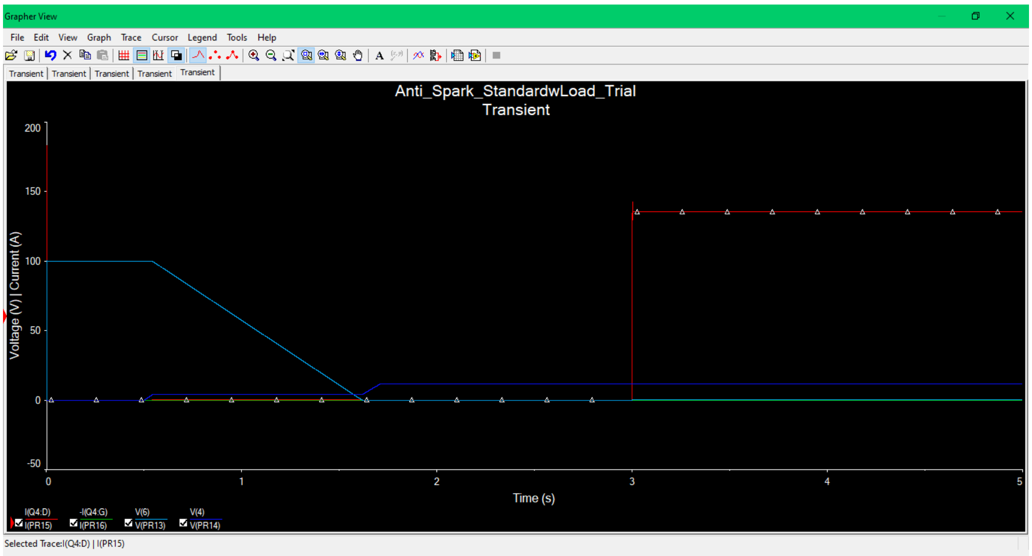

Figure 5: Graph result for MOSFET

The PCB prototype design has been tested in the laboratory at FKEE, UTHM. As the mentioned in the objective, the arcing issue during installing the DC source and ESC has been achieved. The inrush current from the source has been resisted by the 1MΩ of the resistor. The PCB design is able to withstand the high voltage from the DC source which is 100.8V. However, the voltage charging from the DC source through the design circuit is slightly slow. It takes more than a minute to fully charge compared to the simulation in NI Multisim. Then, the temperature of the PCB prototype is not very high, so the PCB will withstand the incoming high voltage.

4. Conclusion

A project aimed to eliminate the electrical arc that produces in a high current DC power system. In this project, the result shows in the simulation that arcing problem can vanish. The findings of some research are helpful in designing the anti-arcing DC circuit breaker. For completing this project, a PCB design is required to demo the circuit design and to show that the arcing problem in the aircraft operation will be solved by dealing with the inrush current from the source to the ESC capacitor. As the result, the PCB prototype has been done and tested in the laboratory.

Acknowledgement

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References

1] Meyer, C. & Kowal, M. & De Doncker, Rik. (2005). Circuit breaker concepts for future high-power DC-applications. Proc IEEE IAS Annual Meeting. 2. 860 – 866 Vol. 2. 10.1109/IAS.2005.1518439.

[2] Teng, Shangfu & Zhang, Zhifeng & Xiao, Liye. (2020). Research on a Novel DC Circuit Breaker Based on Artificial Current Zero-Crossing. IEEE Access. PP. 1-1. 10.1109/ACCESS.2020.29755080.

[3] Behzad, Mehdi & Darvish Gohari, Hamed & Mohammadi-Dehabadi, A. (2018). Vibration effect on electrical resistance fluctuations in electrical connectors. Engineering Solid Mechanics. 6. 299-306. 10.5267/j.esm.2018.9.002.