

論文 / 著書情報
Article / Book Information

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種別(和文)	論文要旨
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論文要旨

THESIS SUMMARY

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Academic Degree Requested Doctor of Engineering

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要旨 (英文 800 語程度)

Thesis Summary (approx.800 English Words)

DC power systems have received considerable attention owing to their cost-effectiveness and reliability. Despite their several advantages, DC interruption in these systems is difficult because DC does not have a natural current-zero. Hence, DC systems require an effective current-interrupting device having a long lifespan and capable of interrupting the DC current faster to prevent damage to the electrical systems or equipment. Mechanical switches have a low contact resistance, but they have the drawback of serious arc discharge. When the mechanical contacts of a switch open to interrupt the DC current, a long-duration arc ignites between the contacts and erodes the contact surface. The arc reduces the lifespan of the switch owing to erosion. The solid-state switches rapidly interrupt current, but they have a high on-state resistance that causes a high power loss in normal operation. A hybrid DC switch comprising a mechanical switch parallelly connected to a semiconductor device has a low resistance and capacity to interrupt a large DC current. The hybrid DC switch can interrupt a small current with an arc-free and short-duration arc for a large current interruption.

The experimental results showed that the arc duration increased up to 14 μ s for a current commutation of 1 kA. For 100 operations of contact opening, the eroded surface caused by the arc accumulated in one area, and the diameter of the eroded surface was larger with increasing commutation current. The maximum height of protrusion and the depth of the hollow of the eroded surface of the contacts increased with increasing commutation current. The arc discharge slightly affected the contact resistance. However, the arc decreased the dielectric strength between the contacts. The dielectric strength mainly decreased due to the effects of protrusion and the metal vapor caused by the arc. The reduction in dielectric strength due to the protrusion was 19%, and that due to the metal vapor was 19% in comparison with the average values for a delay of 700 μ s from the time of contact opening until the time of applying a high voltage for the current commutation of 1 kA. The effect of metal vapor was almost constant after a delay of 2 ms. When a two-series connection of SiC-MOSFETs was parallelly connected to the contacts, the commutation time was longer than that in the case of one SiC-MOSFET. With the two-series connection of the SiC-MOSFETs, the dielectric strength was lower than that of one SiC-MOSFET.

A join of copper and carbon contact had a low resistance of 0.2 m Ω and an increased threshold current of arc-free commutation up to 700 A. Arc-free commutation was performed by exploiting the increase in the contact resistance from the copper material to the carbon of the left contact. However, when the contact area changed from copper to carbon, a spike voltage occurred. The spike became an arc discharge when the current increased to 800 A. An arc trace was observed on the copper. A copper-nichrome contact commutated a current up to 400 A without arc discharge. When the copper-nichrome contact commutated a current of 500 A, an arc discharge was observed at the nichrome material of the contact. During the closing operation of the copper-carbon contact, a bouncing arc was not observed because a spring inserted at the right contact maintained contacting between the right and left contacts close without bouncing.

The simulation was performed by using COMSOL Multiphysics software. The results showed that the contact area of the left and right contacts moved downward from the copper material to the carbon material, which increased the contact resistance with time. The temperature of the contacts during their movement did not exceed the boiling temperature of the contact material, indicating the possibility of increasing the arc-free commutation current. The contact current and voltage waveforms showed the same tendency as in the experiment, particularly for a pulse voltage that occurred when

the contact area changed from the copper to the carbon material. Accordingly, a copper-carbon alloy with a resistivity between those of copper and carbon was inserted between the copper and the carbon to eliminate the pulse. Consequently, the current and voltage of the contact were smoother than those in the case without the copper-carbon alloy, and the pulse was eliminated.

In the future experiment, a copper-carbon alloy with a resistivity of $3 \times 10^{-5} \Omega \cdot m$ will be inserted between the copper and the carbon to smoothly increase the contact resistance during contact opening. With a smooth increase in the contact resistance, the current will be smoothly commutated to that of the SiC-MOSFET, which can prevent a spike voltage that may potentially become an arc discharge. In conclusion, the arc duration was short for current commutation. The arc did not significantly affect the contact resistance but decreased the dielectric strength between the contacts. The copper-carbon contact can commutate a current up to 700 A with arc-free commutation. The hybrid DC switch possibly commutates a large current for arc-free commutation through the insertion of a material having a resistivity between those of copper and carbon.

備考：論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。

Note : Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1 copy of 800 Words (English).

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