Hybrid Switch with Tungsten-clad Copper Contacts for Arc-free On/Off Switching up to DC 400 A

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K. Yasuoka, Y. Yamada, M. Chen

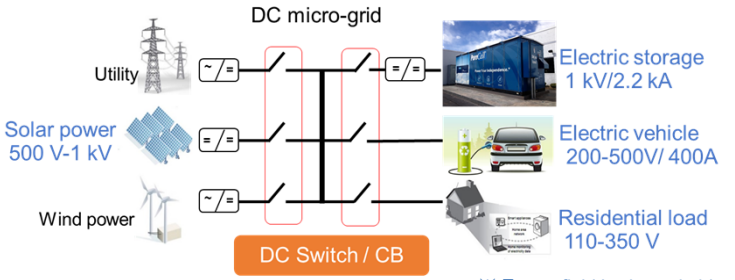
Tokyo Institute of Technology, 2-12-1, Ookayama, Meguro-ku, Tokyo 152-8552, Japan
Phone:+81-3-5734-2900 E-mail: yasuoka@ee.titech.ac.jp

Summary

Direct current (DC) switch is one of the key components of DC power distribution systems. A hybrid DC switch, consisting of mechanical contacts, semiconductor devices, and metal-oxide varistors, can shorten the arc duration during the closing and opening periods of the switch; however, a short duration arc still causes contact erosion and induces a reignition of the arc. We have developed a tungsten-clad copper contacts that enables an arc-free DC switching up to 400 A, because the tungsten part increases the boiling voltage and the copper part decreases the maximum temperature at the contact spot. Both the making and breaking arc discharges were suppressed by this hybrid switch. The commutation period during the opening process of the switch was below 0.3 ms, and the current interrupting period was 2.4 ms for 400 A.

Background

Demand Fields of DC Switch and Circuit Breaker (CB)



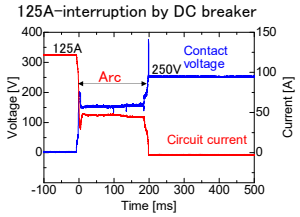
※ Target field is shown in blue

Conventional DC Switch/CB

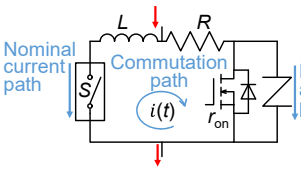
Mechanical
- ◎ Low cost
- ◎ Low energy loss
- × Serious arc erosion
- × Low reliability

Semiconductor
- ◎ No arc erosion
- ◎ Long Lifespan
- × High cost and energy loss
- × Large size (poor heat dissipation)

Mechanical DC Breaker: VI waveforms and Arc



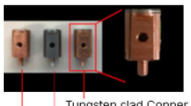
Hybrid DC Switch/CB



- ◎ Low energy loss
- ◎ Less arc erosion
- ◎ High Reliability
- ◎ Long lifespan
- × High cost
- × No track record

Experimental Setup and Result

Experimental Setup



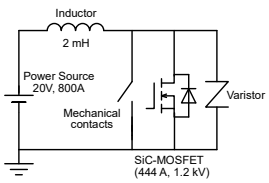
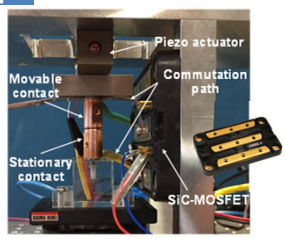


Fig. 1&5



	Melting Voltage	Boiling Voltage	Resistivity	Thermal conductivity	Young's modulus
Cu	0.43 V (1083°C)	0.8 V (2582°C)	1.7 10^{-8} Ωm	398 $Wm^{-1}K^{-1}$	110 10^{9} Nm^{-2}
W	1.1 (3380°C)	2.1 (5527°C)	5.3 10^{-8} Ωm	178 $Wm^{-1}K^{-1}$	345 10^{9} Nm^{-2}

Time Sequence and Vcontact w/o MOSFET

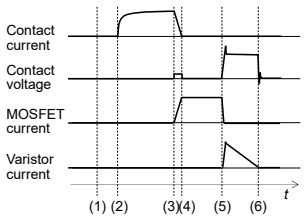


Fig. 6

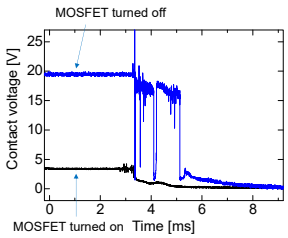


Fig. 7

Arc-free condition

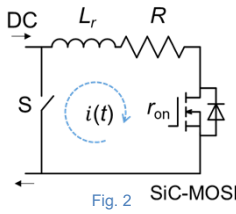


Fig. 2

Boiling voltage / Contact voltage / Residual inductance / Circuit and Turn-on resistance

$$V_b \geq v_c(t) = L_r \cdot \frac{di(t)}{dt} + (R + r_{on}) \cdot i(t) \quad (1)$$

Maximum temperature of the contact surface by HOLM [8]

$$T_{max} = \sqrt{\frac{V_c^2}{4L} + T_0^2} \quad (2)$$

Suppression of Arc and Arc-free Interruption

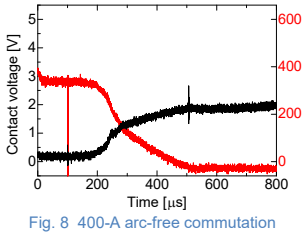


Fig. 8 400-A arc-free commutation

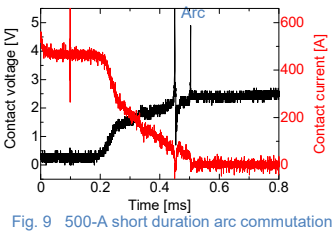


Fig. 9 500-A short duration arc commutation

Piezo driver and Gap length

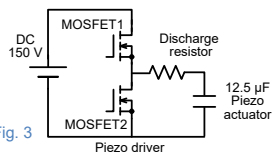


Fig. 3

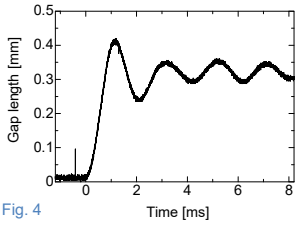


Fig. 4

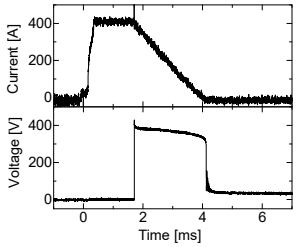


Fig. 10

- Commutation period < 0.3 ms in Fig. 8
- Contact voltage < 3V ---> arc-free
- MOSFET turned off at 1.7 ms in Fig. 10
- Switch voltage increased to 400 V that was limited by the varistors
- Interrupting time of arc-free 400 A was 2.4 ms

ACKNOWLEDGEMENTS
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