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Operating characteristics of arc-induction type DC circuit breaker with permanent magnets

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Abstract

- In this study, a new type of arc-induced direct current (DC) circuit breaker is proposed as a mechanical circuit breaker suitable for DC systems. It consists of mechanical contacts, induction needles, an induction ring, and a ground line.
- In this study, the cut-off characteristics of the arc-induced DC circuit breaker were analyzed using the Maxwell software. A simulation model was designed, and the electrical field distribution was analyzed according to the contact pole pitch.
- As a result, it was possible to investigate the blocking characteristics of the arc-induced DC circuit breaker through the simulation and experiment.

Introduction

- In this study, a method of naturally exhausting arcs by indirectly absorbing them was researched on, and a new type of arc-induced DC circuit breaker was proposed, consisting of an anode and a cathode (blocking contacts) as well as conical induction needles.
- In addition, there is a ground line connected in series to the induction needles. The proposed circuit breaker is economically beneficial because it consists only of mechanical elements.
- The induction needles were designed for the strong intensity of the electrical field, and it induces an arc generated between the blocking contacts to the ground line. The induced arc flows to the ground along the ground line to be exhausted.
- In this study, the blocking operation of the arc-induced DC circuit breaker was simulated using the Max-well 3D software. Moreover, a prototype was fabricated based on the simulation parameters, and short-circuit experiments were performed under the same conditions as those for the simulation. The results were compared and analyzed.

Simulation

1) Design

- It is the arc-induced DC circuit breaker model designed for the simulation.
- A voltage of +250 V was applied to the anode, and -250 V to the cathode. No voltage was given to the ground line. The cathode was moved in the opposite direction to the anode, from 0 to 40 mm, at 0.1 mm intervals.

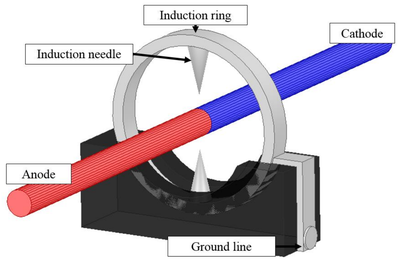

Fig. 1. Simulation model of Arc-induction type DC circuit breaker

2) Results

- It is the arc-induced DC circuit breaker model designed for the simulation.
- A voltage of +250 V was applied to the anode, and -250 V to the cathode. No voltage was given to the ground line. The cathode was moved in the opposite direction to the anode, from 0 to 40 mm, at 0.1 mm intervals.

Parameters for the composition of the arc-induction type DCCB for the simulation (extinguishing part)

Composition	Resource	Value
Contacts (Anode & Cathode)	Material	Cooper (Cu)
	Diameter [mm]	12
	Length [mm]	150
Induction needle	Material	Cooper (Cu)
	Diameter [mm] (bottom)	10
	Diameter [mm] (top)	0
	Height [mm]	23
Induction ring	Diameter [mm] (outside)	80
	Diameter [mm] (inside)	70
	Height [mm]	5

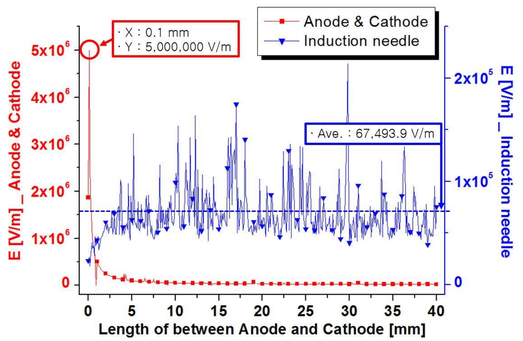

Fig. 2. Graph of the simulation results

Experiments

1) Design

- A pneumatic cylinder was used for the movement of the cathode. This could cause a very fast opening operation because the object was pulled using the pressure of the air.
- The atmospheric pressure level that was used in the experiment ranged from 7.9 to 8 kPa.

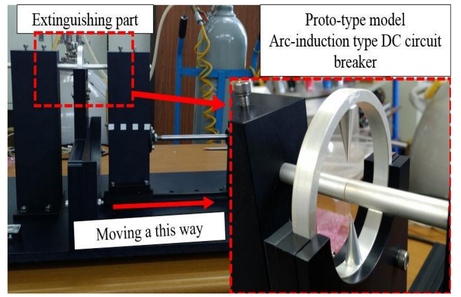

Fig. 3. The prototype model of the Arc-induction type circuit breaker

Parameters for the composition of the arc-induction type DCCB for the experiment (extinguishing part)

Composition	Resource	Value
Contacts (Anode & Cathode)	Material	Cooper (Cu) Plating silver(Ag)
	Diameter [mm]	12
	Length [mm]	150
Induction ring	Material	Cooper (Cu) Plating silver (Ag)
	Diameter [mm] (Bottom)	10
	Diameter [mm] (top)	0
	Height [mm]	23
Induction ring	Diameter [mm] (outside)	80
	Diameter [mm] (inside)	70
	Height [mm]	5

2) Results

- It is the results of the five experiments performed under the same conditions as in the experimental design. Five experiments were performed to improve the reliability of the opening operation of the prototype.
- The air pressure was approximately 8.0 kPa, and the applied voltage was approximately 8.0 kPa., and the applied voltage was current was approximately 45 A.

	A [m/s]	B [m/s]	C [m/s]
Test 1	327	628	355
Test 2	156	469	182
Test 3	254	554	200
Test 4	271	566	301
Test 5	345	602	300

Test blocking time for test 1 ~ 5 (Anode & Cathode)

	Breaking speed [m/s] (B-A)	Average [m/s]
Test 1	301	
Test 2	313	
Test 3	300	293.2
Test 4	295	
Test 5	257	

The speed of pneumatic cylinder through the test 1 ~ 5

3) Consideration

- First, when the blocking contacts of the arc-induced DC circuit breaker were in contact (steady state) in the simulation data, it appears that the potential difference observed from the induction needle was affected by the distance between the blocking contact and the induction needle (approximately 2 mm).
- Second, the error rate of the pneumatic cylinder's pressure difference, which affects the operation speed of the arc-induced DC circuit breaker, was reduced through five experiments.

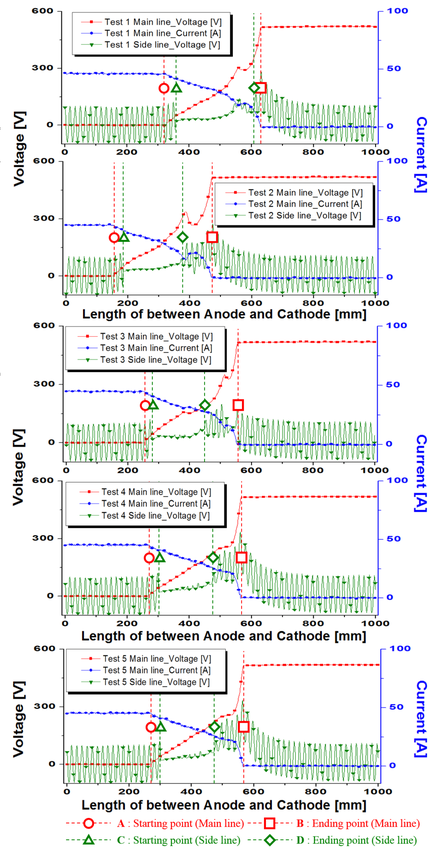

Fig. 4. Graphs of the experiment results (Test 1~5)

Conclusion

- The simulation results confirmed that a high electric field was formed when the system changed from a steady state to a transient state. From the induction needles, the movement of the electrical field in proportion to that of the blocking contact could be confirmed.
- Moreover, a prototype was fabricated based on the simulation model, and short-circuit experiments were simulated. As a result, the voltage and current characteristics of the mechanical circuit breaker in the main line were identified, and it was possible to investigate the voltage characteristics of the induction needle.

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