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Characteristics of Superconducting Coil-type DC Fault Current Limiter to increase stability in DC power system

Hye-Won CHOI[1], Hyo-Sang CHOI[1], Dong-Chul CHUNG[2], In-Sung JEONG[1], Jun-Beom KIM[1], Sang-yong PARK[1]

1. CHOSUN University, South of KOREA
2. Korean Institute of Carbon Convergence Technology

CHOSUN UNIVERSITY 1946

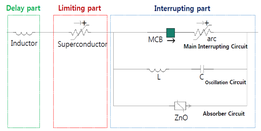
Abstract

- The simulation results showed that the interruptIn this study, SC-DC FCL was proposed. The interruption and operation characteristics of the SC-DC FCL were analyzed which is applied to the distributed-generation (DG)-type 7.98 kW-class PV system. EMTDC/PSCAD have used for the simulation.
- Interruption operation time of the mechanical circuit breaker (MCB), the power burden applied to the MCB, and the peak value of the fault current were significantly reduced by the application of the SC-DC FCL.
- In addition, when the SC-DC FCL was applied, the fault current flowing through the line was limited by approximately 78 % or more.

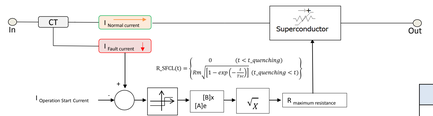
Superconductor Coil-type DC Fault Current Limiter(SC-DC FCL)

1) SC-DC FCL Structure

- SC-DC FCL is a system that applies a current-limiting technology and a current-delay technology to the interruption technology.
- It consists a current-delay part and a current-limiting part and an interruption part



[SC-DCIS Structure]



[Superconductor Modeling Algorithm]

2) Delay part

- Role : to limit the maximum value of the fault current during an fault.

3) Limiting part

- Role : to limit the maximum value of the fault current during an fault.
- A resistive superconductor, which has benefits of simple structure, principle and excellent current-limiting characteristics and the recovery, was applied to the current-limiting part.
- The Superconductor operates without impedance in the normal condition, and does not cause any damage to the line. When an fault occurs, however, the quench operation generates arbitrary impedance within a few milliseconds to limit the fault current.

4) Interrupting part

- Role : to open the fault line at the time of an fault.
- A mechanical DC circuit breaker (M-DCCB) was applied to the interruption part.
- The M-DCCB consists of a main interruption circuit, an oscillation circuit, and an absorbing circuit.

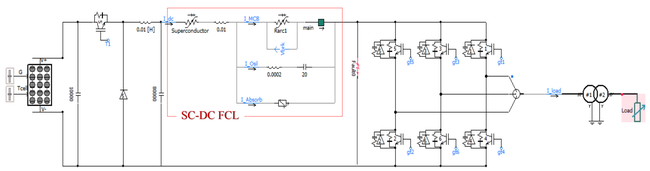
$$I_{\_MCB} = I_{\_dc}\left\{1 + e^{-0.5L\frac{du_{arc}}{dI_{\_MCB}}t}\, sin\left(\sqrt{\frac{1}{LC}}\, t\right)\right\}$$

[Interruption current eq.]

$$\frac{1}{g_m}\frac{dg_m}{dt} = \frac{1}{\tau_m}\left(\frac{u_{arc} \cdot i_{arc}}{P_0} - 1\right)$$

[Mayr arc method]

5) Simulation circuit modeling (Distributed generation PV grid)



[SC-DC FCL modeling value]

Part	Element		Abb.	Value	Unit
Delay	Inductor			0.01	mH
Limiting	Superconducting	transition characteristic time constant	Tsc	0.75	-
		Maximum resistance	Rm	4	Ω
		Operate Starting Current	Iosc	5	kA
Interruption	MCB	Mechanical type			-
	Arc	Mayr arc type			-
		Arc time constant	τ_{a0}	0.3	μs
		Arc cooling power	Po	50,000	kW
	Oscillation circuit	Inductor	L	0.02	mH
		Capacity	C	20	μF
	Absorbing circuit	ZnO	-	80	kV

[PV grid modeling value]

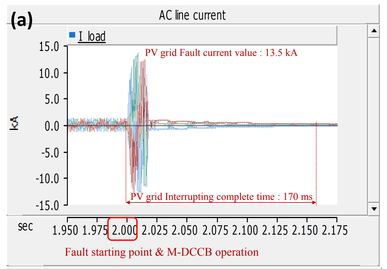
Part	Element		Abb.	Value	Unit
PV	PV array	Series connection	Ns	20	module
		Perall connection	Np	20	module
	PV module	PV array short circuit current	Isc	160.1	A
		PV array open circuit voltage	Voc	1700	V
		Maximum power current	Imp	130.9	A
		Maximum power voltage	Vmp	61	V
		PV maximum power	Pmax	7.98	kW
	Etc.	Reference irradiation	Sref	1000	w/m²
		Reference cell temperature	Tref	25	℃
Transformer	Primary winding		T1	0.23	kV
	Secondary winding		T2	0.6	kV

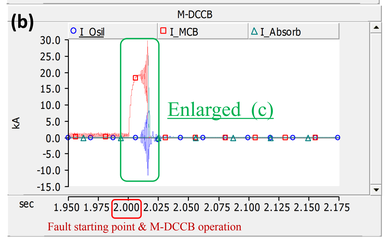
- Fault type : Pole to Pole
- Fault time : 2 s
- Fault period : 3s
- M-DCCB operation signal time : 10 ms after fault occur
- Analysis point

- Interruption operation of M-DCCB according to presence or absence of superconductor

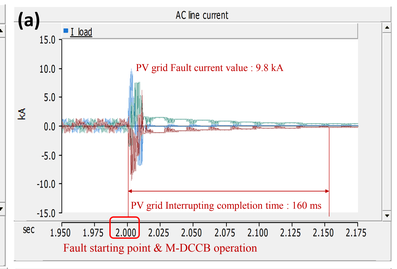
Simulation Analysis

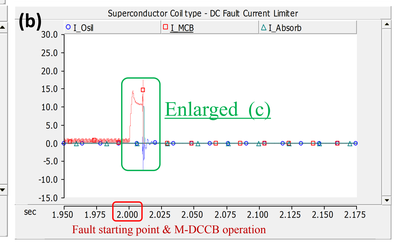
1) Without Superconductor (M-DCCB)

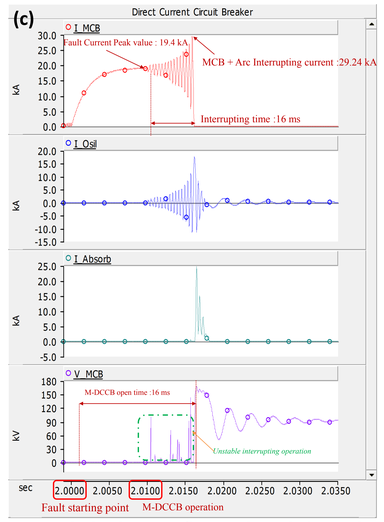


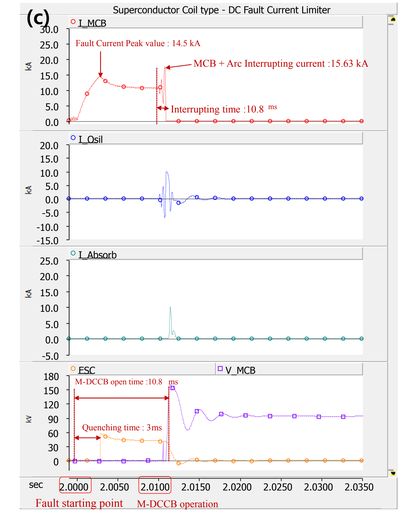


2) With Superconductor (SC-DC FCL)









(a) the load current flowing through the AC line before entering the step-up transformer
(b) the interruption characteristics of the M-DCCB
(c) an enlarged graph of the M-DCCB or SC-DC FCL interruption characteristics.

3) DATA

	Without SC (M-DCCB)	With SC (SC-DC FCL)
PV array normal output current	0.6 kA	0.6 kA
Fault current peak value	19.4 kA	14.5 kA
MCB+Arc interruption current value	29.24 kA	15.63 kA
Interruption operation complete time	2.016 s (16 ms)	2.0105 s (10.5 ms)
Absorbing circuit arc extinguishing complete time	2.0182 s (18.2 ms)	2.0121 s (12.1 ms)
PV grid Fault current value	13.5 kA	9.8 kA
PV grid Interruption operation complete time	2.170 s (170 ms)	2.160 s (160ms)
M-DCCB power burden	35.897 MW	6.016 MW
Fault current limiting rate	-	78.22 %

Conclusion

➢ **The SC-DC FCL combined with a superconductor showed better interruption characteristics than M-DCCB.**

1. The interruption operation time of the M-DCCB by about 5.5 ms.
2. The fault current interruption time in the PV grid by approximately 10 ms.
3. More than half of the DC fault current and fault interruption current was limited in the PV system.
4. The power burden on the M-DCCB about 5.9-times.
5. The unstable operation of the breaker did not occur.

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