

Analysis of Over-Current Withstand Capability of Discrete SiC MOSFETs for Interrupting MOV Paths in Solid-State Circuit Breakers

David Schadow¹, Jochen Kurfiss¹, Wenqi Zhou², Karl Oberdieck¹

¹ Robert Bosch GmbH, Germany

² Bosch (China) Investment Ltd. China

INTRODUCTION

- In Solid-State Circuit Breakers (SSCBs), Metal Oxide Varistors (MOVs) are essential for clamping overvoltage's. However, to prevent the MOV from thermal runaway and failure after clearing a fault, its current path must be reliably interrupted to avoid leakage currents.
- This work presents an investigation into the use of discrete Silicon Carbide (SiC) MOSFETs to perform this interruption.
- The study focuses on quantifying the over-current withstand capability of these devices when exposed to the surge currents from the MOV commutation path.
- A characterization setup was developed to evaluate the ruggedness for these operating conditions and analyze the degradation/destruction mechanisms.

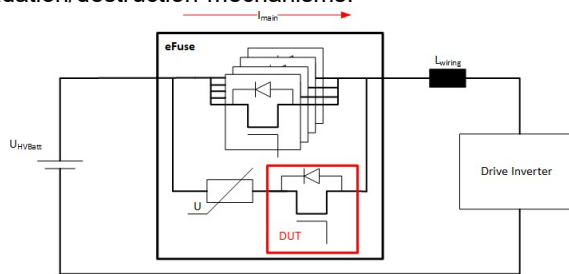


Fig. 1 Solid-state circuit breaker topology

MOV SWITCH STRESS PROFILE

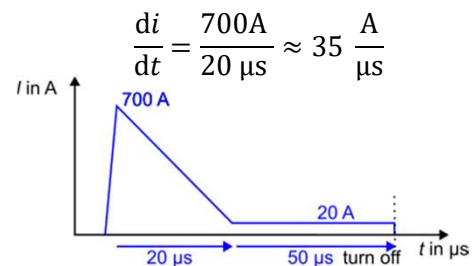


Fig. 2 Current trough DUT during interruption

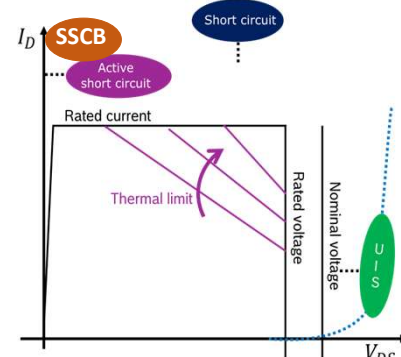


Fig. 3 Safe operating area (SOA) with special operating conditions

Test Principal

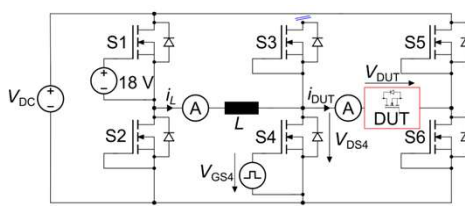


Fig. 4 Topology based on B6 module

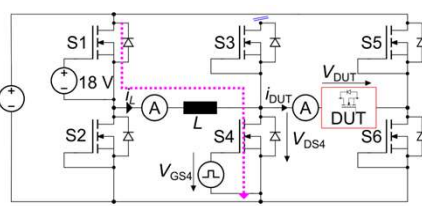


Fig. 5 Charging time

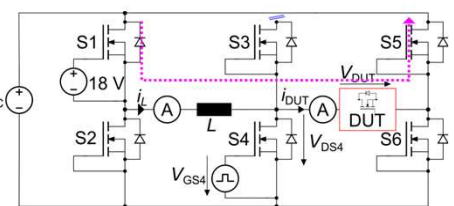


Fig. 6 Testing time

Table 1 Switching states

Switch	Charging	Testing
S1	on	on
S2	off	off
S3	disconnected	disconnected
S4	on	off
S5	off	off
S6	off	off
DUT	on	on

- Test circuit is based on a standard three-phase B6 power module
- The discharge profile can be actively modified by adjusting the gate-source voltage of the high-side MOSFET (S5), allowing for precise control over the test conditions.

Analysis of Over-Current Withstand Capability of Discrete SiC MOSFETs for Interrupting MOV Paths in Solid-State Circuit Breakers

David Schadow¹, Jochen Kurfiss¹, Wenqi Zhou², Karl Oberdieck¹

¹ Robert Bosch GmbH, Germany

² Bosch (China) Investment Ltd. China

CHARACTERIZATION SETUP

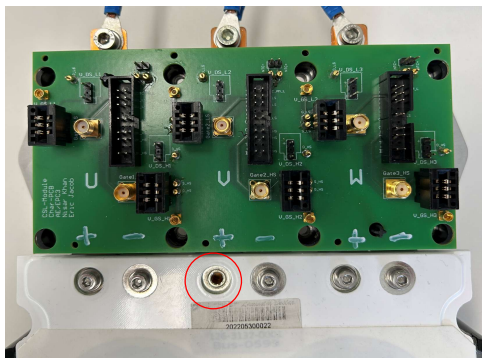


Fig. 7 B6 bridge



Fig. 8 Charging inductor



Fig. 9 DUT including its connector

TEST WAVEFORM

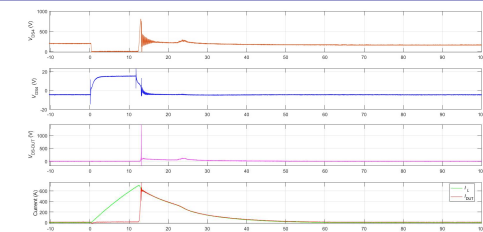


Fig. 10 Commissioning of the test setup

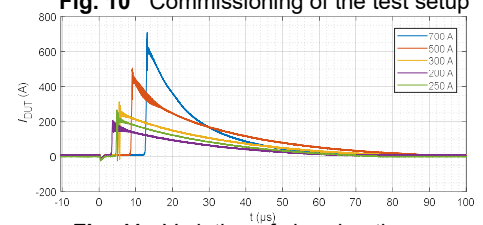


Fig. 11 Variation of charging time

RESULTS

Table 2 1st test runs

Current	#Events
700 A	0
500 A	0
300 A	3
250 A	6
200 A	Tested up to 500 Pulses



Fig. 12 Physical analysis of failure DUTs

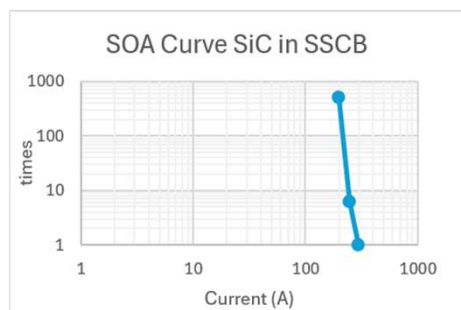


Fig. 13 SOA Curve of SiC in SSCB

- Repeating time dramatically decreases when the current increases to about 250A, at 300A DUT could break after only 2 pulses.
- Delamination could be found at the front or the back side

CONCLUSION

- This paper investigated the essential role of Silicon Carbide (SiC) MOSFETs in reliably interrupting the current path of Metal Oxide Varistors (MOVs) in Solid-State Circuit Breakers (SSCBs).
- By breaking the MOV current path, SiC MOSFETs effectively mitigate the risk of thermal runaway and avoid leakage currents.
- A dedicated characterization setup based on a B6 bridge module was developed to characterize the SiC MOSFETs capability with this specific load profile.
- The setup allows for precise quantification of the overcurrent withstand capability when exposed to the surge currents from MOV commutation paths, providing insights into the SiC MOSFETs ruggedness and degradation mechanisms.
- This work significantly contributes to the development of highly reliable SSCBs by validating SiC MOSFETs as a robust solution for this protection function.