Scalable MV/HV Super Cascode Power Module
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Overview

Background
Double-digit-kV semiconductor switches are demanded by many applications, such as solid state transformers, solid state circuit breakers and pulse power applications. At above 15kV, the only widely available devices are IGBTs, which suffer from secondary breakdown and slow switching speed. A majority carrier device is highly demand for such applications, switching at tens to hundreds of kV, and kHz.

Project Goals
This project aims to solve the following problems:
1. To allow series connection of massive amount of JFETs for higher blocking voltage.
2. To allow reliable operation with tolerance to avalanche breakdown.
3. To reduce switching loss and to increase switching speed.

Method

Unit SCPM Topology
This work is based on the previous 6.5kV SCPM, which is capable of switching at 6.5kV, 100A, 175kHz.

The switching energy loss of SCPM is quadratically dependent on device stages N, which limits the maximum stages which can achieve without creating too much switching loss.

\[ E_s = \frac{1}{4} (Q_{G} - Q_{D}) V_{DS} (N^2 - N) \]

SCPM-J Topology
To reduce switching loss, a long string of JFETs can be broken down to several sub-strings, thus to reset N periodically.

By removing the MOSFET, an SCPM can be used as a single larger JFET, called Unit SCPM. Unit SCPMs can be connected in a larger SCPM for higher voltage blocking.

Results

Conclusions
A 20-stage SCPM-J based on 2*2*5 configuration (2 JFETs per smaller Unit SCPM, 2 smaller Unit SCPMs per larger Unit SCPM, and 5 larger Unit SCPMs in final SCPM-J) was designed and simulated.

Simulation shows 19% reduction on switching loss compared with a 20-stage SCPM based on previous work.

Impacts
This work enables fast switching on double-digit-kV circuits, which enables sub-transmission level SSTs and SSCBs. In addition, this work enables high voltage locomotive inverters and other applications where fast switching at MV/HV is needed.

Future Work
Test modules will be fabricated to verify this design, and a tester will be manufactured to characterize the new module.

Applications in device testers, solid circuit breakers and dielectric liquid cooled modules are being proposed.

References
3. X. Li, H. Zhang, P. Alexandrov and A. Bhalla, "Medium voltage power switch based on SiC JFETs," 2016 IEEE Applied Power Electronics Conference and Exposition (APEC), Long Beach, CA.