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

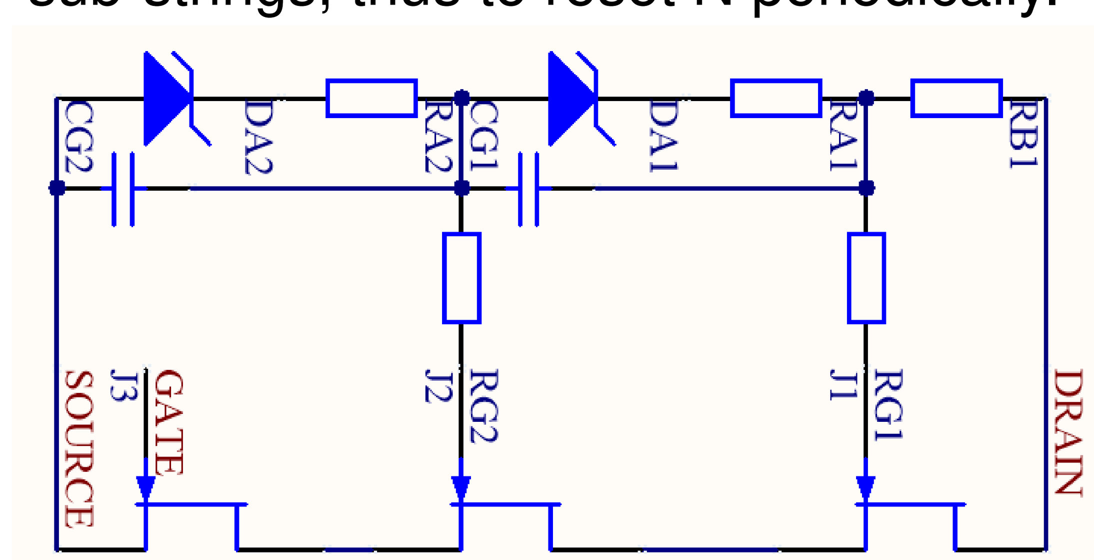
This work is based on the previous 6.5kV SCPM, which is capable of switching at 6.5kV, 100A, 175kHz.

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

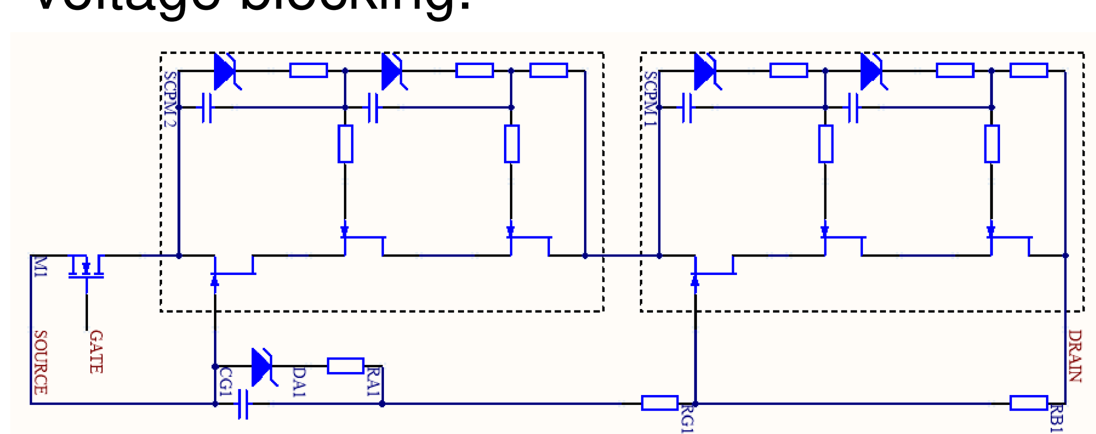
$E_B = 1/4 * (Q_G - Q_D) * V_{DS} * (N^2 - N)$

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.

Configuration	JFET Switching Energy	Balancing Network Resistor Energy
N1=20, N2=1	37.52mJ	1955.73uJ
N1=2, N2=2, N3=5	30.40mJ	1514.76uJ
Loss Reduction	18.98%	22.55%

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 verity 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

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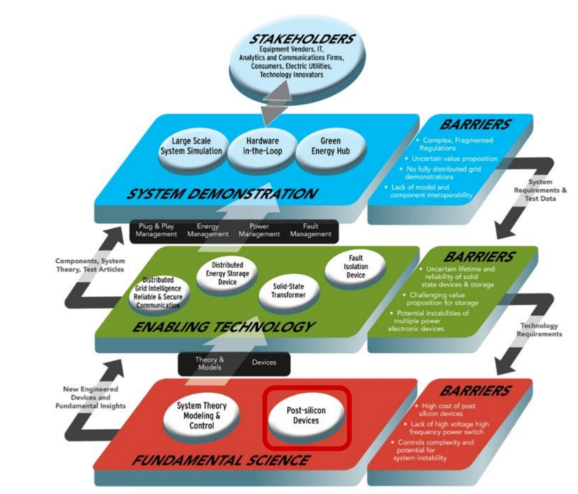

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