An Improved Turn-on Switching Transient Model of 10 kV SiC MOSFET

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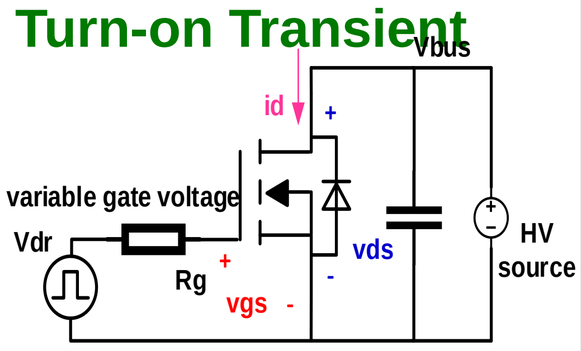
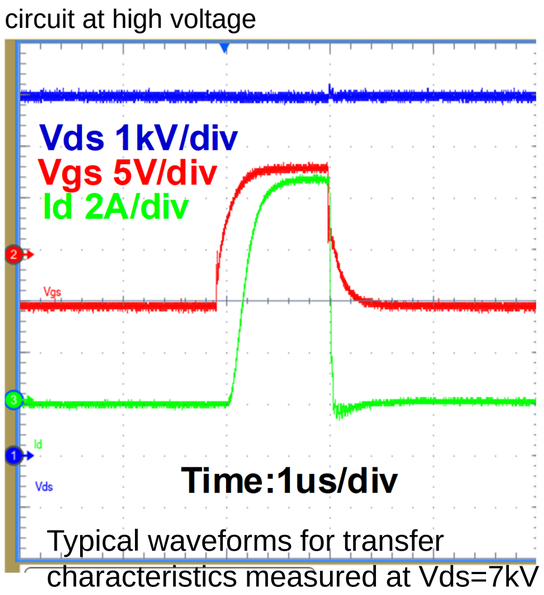
Background

- The emerging 10 kV SiC MOSFET brings great benefit for medium and high voltage applications. Accurate switching transient modeling of the 10 kV SiC MOSFETs is critical for successful application.
- Conventional models based on curve tracer results fail to consider transconductance and dynamic gate charge during actual high voltage turn-on switching transient, and shows obvious discrepancies compared to experiments.
- Transconductance varies under different drain-source voltage due to SiC MOSFET short channel effect and drain induced barrier lowering effect. Dynamic gate-drain charge under MOSFET channel turn-on condition is different from static gate-drain charge when MOSFET channel is off.

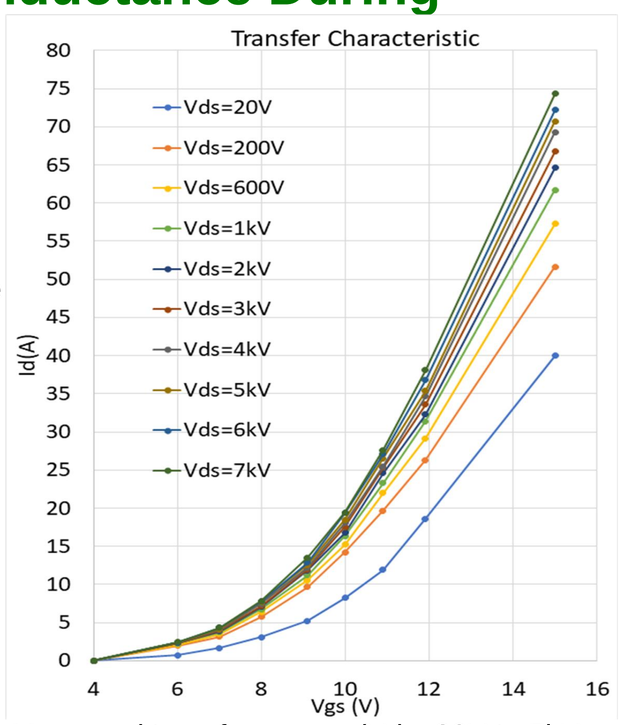
High Voltage Transconductance During Turn-on Transient



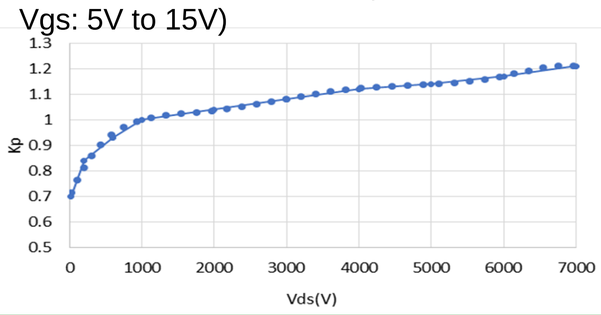
Transfer characteristics measurement circuit at high voltage



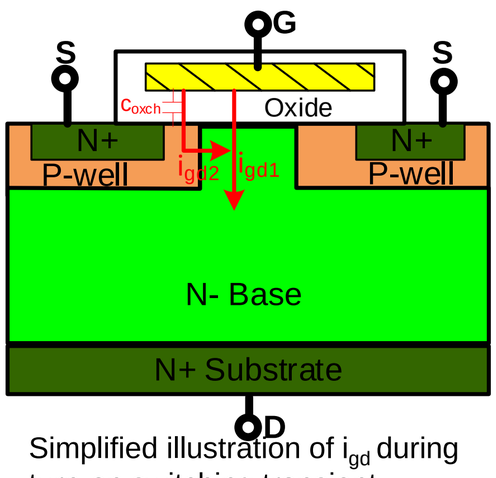
Typical waveforms for transfer characteristics measured at Vds=7kV and Vgs=8V



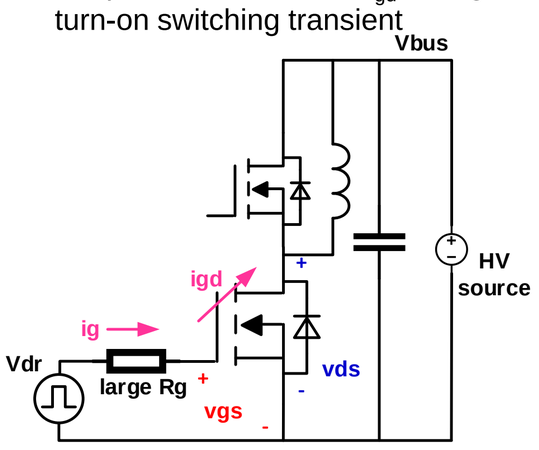
Measured transfer curves (Vds: 20V to 7kV, Vgs: 5V to 15V)



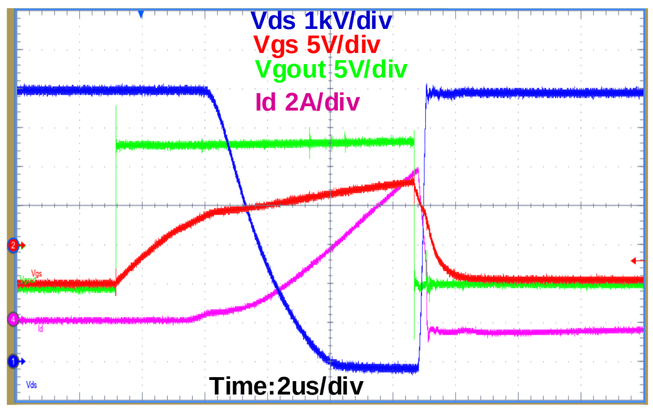
Dynamic Gate-drain Charge During Turn-on Transient



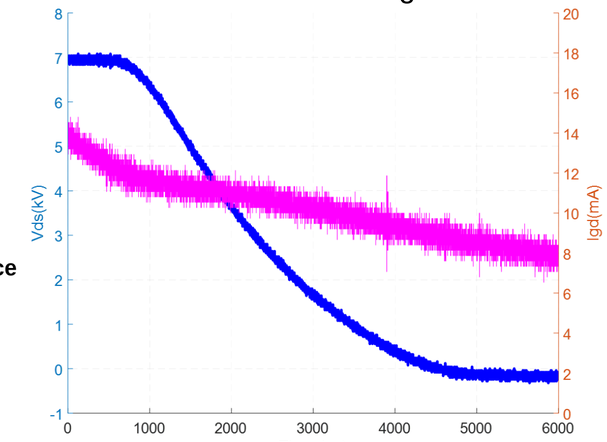
Simplified illustration of i_{gd} during turn-on switching transient



Dynamic charge Q_{gd_dy} measurement circuit

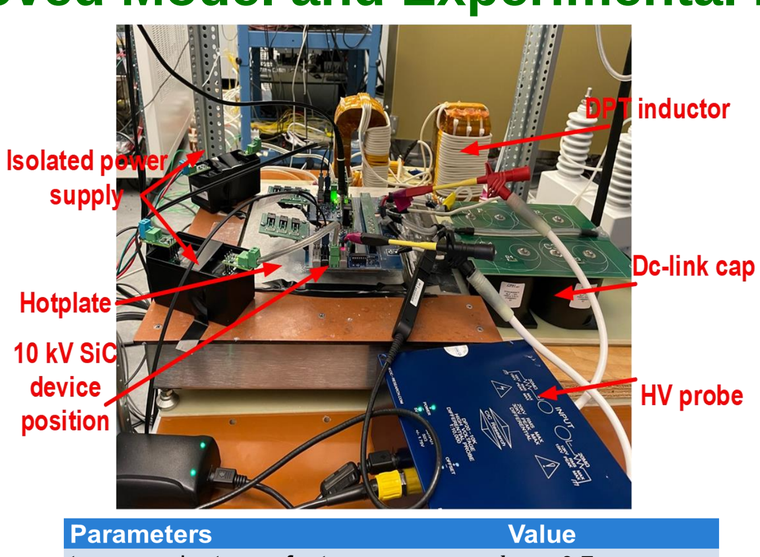


Typical waveforms for dynamic Q_{gd_dy} measured at 7kV bus voltage



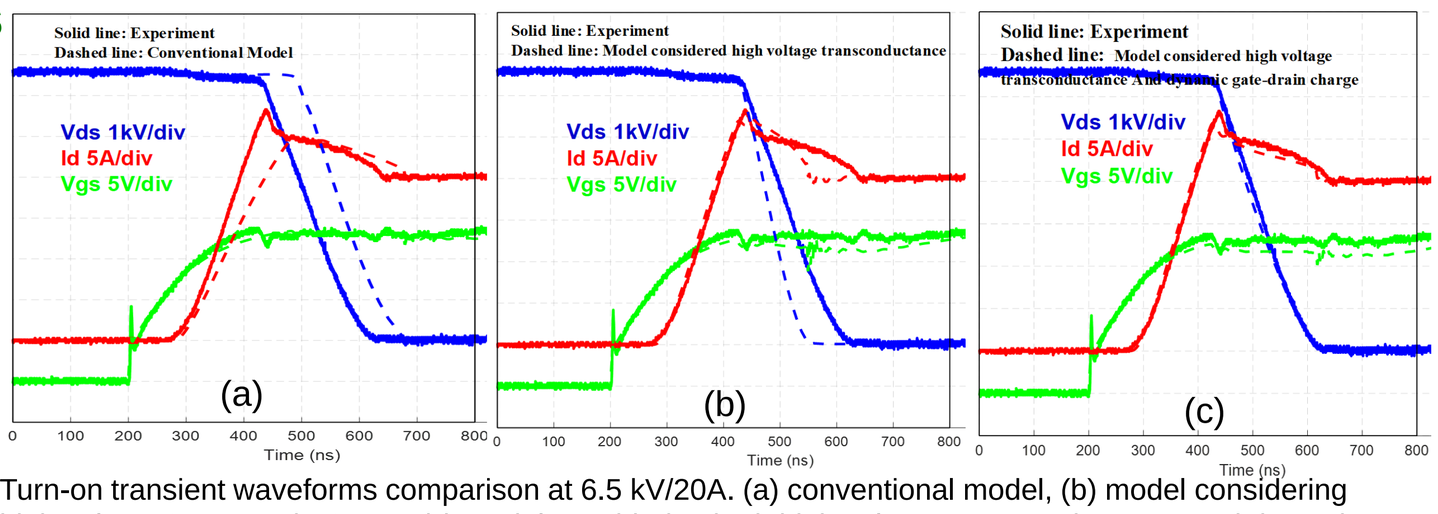
Waveforms of i_{gd} and V_{ds} at 7kV bus voltage

Improved Model and Experimental Results

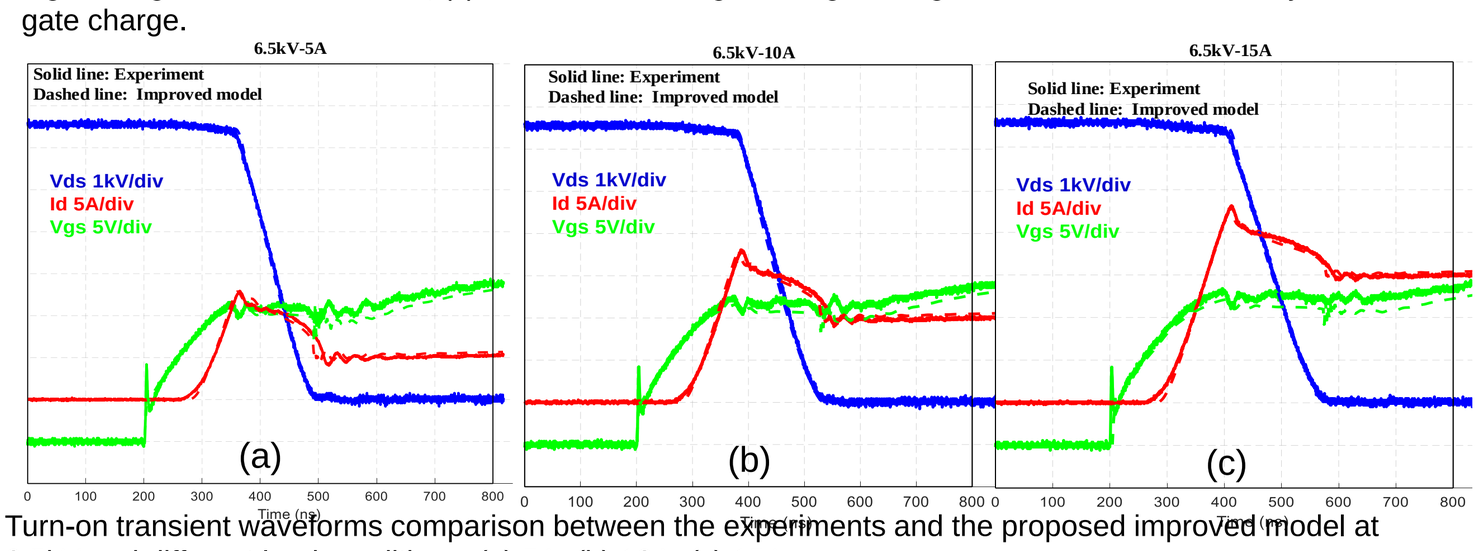


Parameters	Value
transconductance factor k_p	$k_p = 0.7$
threshold voltage v_T	$v_T = 4.1V$ (25°C)
R_B	$380\ m\Omega$
C_{gs}	$6.3\ nF$
parameters for C_{gd}	$C_{gdi} = 1000\ pF, C_{gdb} = 50\ pF$ $M = 1/3$
parameters for C_{ds}	$C_{dsi} = 10\ nF, C_{dsb} = 2.5\ nF$ $M = 1/2$

Eon (mJ)	5A	10A	15A	20A
Experiment	7.3	12.03	18.25	26.02
Proposed Model	7.23 (-0.96%)	11.85 (-1.5%)	17.87 (-2.08%)	25.46 (-2.15%)
Conventional Model	7.1 (-1.78%)	12.38 (+2.91%)	19.75 (+8.22%)	30.49 (+17.18%)



Turn-on transient waveforms comparison at 6.5 kV/20A. (a) conventional model, (b) model considering high voltage transconductance, (c) model considering both high voltage transconductance and dynamic gate charge.



Turn-on transient waveforms comparison between the experiments and the proposed improved model at 6.5kV and different load conditions. (a) 5A, (b) 10A, (c) 15A.

Conclusions

- An improved turn-on switching transient model of the 10kV SiC MOSFET which considers the high voltage transconductance and dynamic gate-drain charge during turn-on transient is proposed and experimentally verified.
- With the proposed model, both current rise stage and voltage fall stage waveforms during turn-on transient match well with that in the experiment. The loss error is within 5% over wide load conditions.