Analyzing Electromagnetic Modes of Integrated Busbars Implemented as Printed Circuit Boards (PCB)

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INTRODUCTION: Information on current sharing between rail capacitors in integrated busbars is important. Field analysis of PCBs is notoriously difficult, mainly because of huge aspect ratios. COMSOL provides means to cope with this problem.

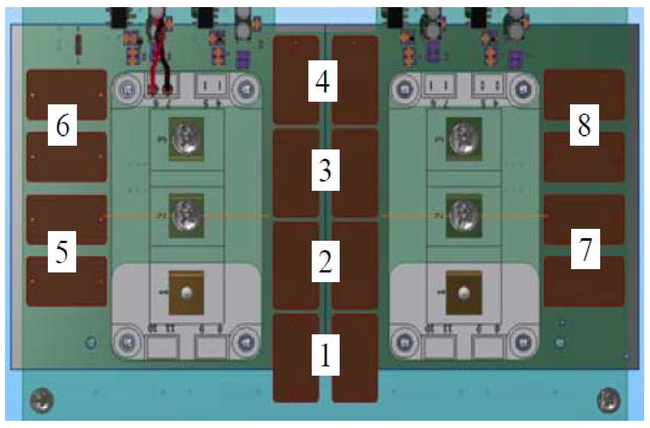

Figure 1. Top view of inverter chassis (half) rated 50kW@60kHz. PCB with 16 rail capacitors (Cr) labeled in pairs 1-8 is on top of 62 mm modules. Cr's provide high frequency currents, relieving reservoir filter.

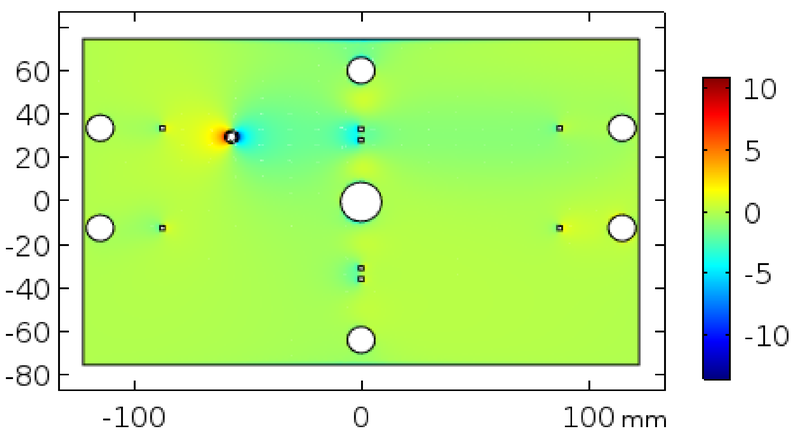

Figure 2. Surface current density (A/mm) of PCB top plate at 120 kHz (Switching frequency is 60kHz). C-LE in forms of handlebars are not shown.

COMPUTATIONAL METHODS: Circuit analysis was done with PSpice. It provided input data for field analysis conducted with Magnetic Field Interface in frequency domain. Transition Boundary Conditions (TBC) and Impedance Boundary Conditions (IBC) were used to exclude bulk copper.

$$(j\omega\sigma - \omega^2\varepsilon_0\varepsilon_r)\boldsymbol{A} + curl\boldsymbol{H} = \boldsymbol{J_e}$$
$$\boldsymbol{B} = curl\boldsymbol{A}$$

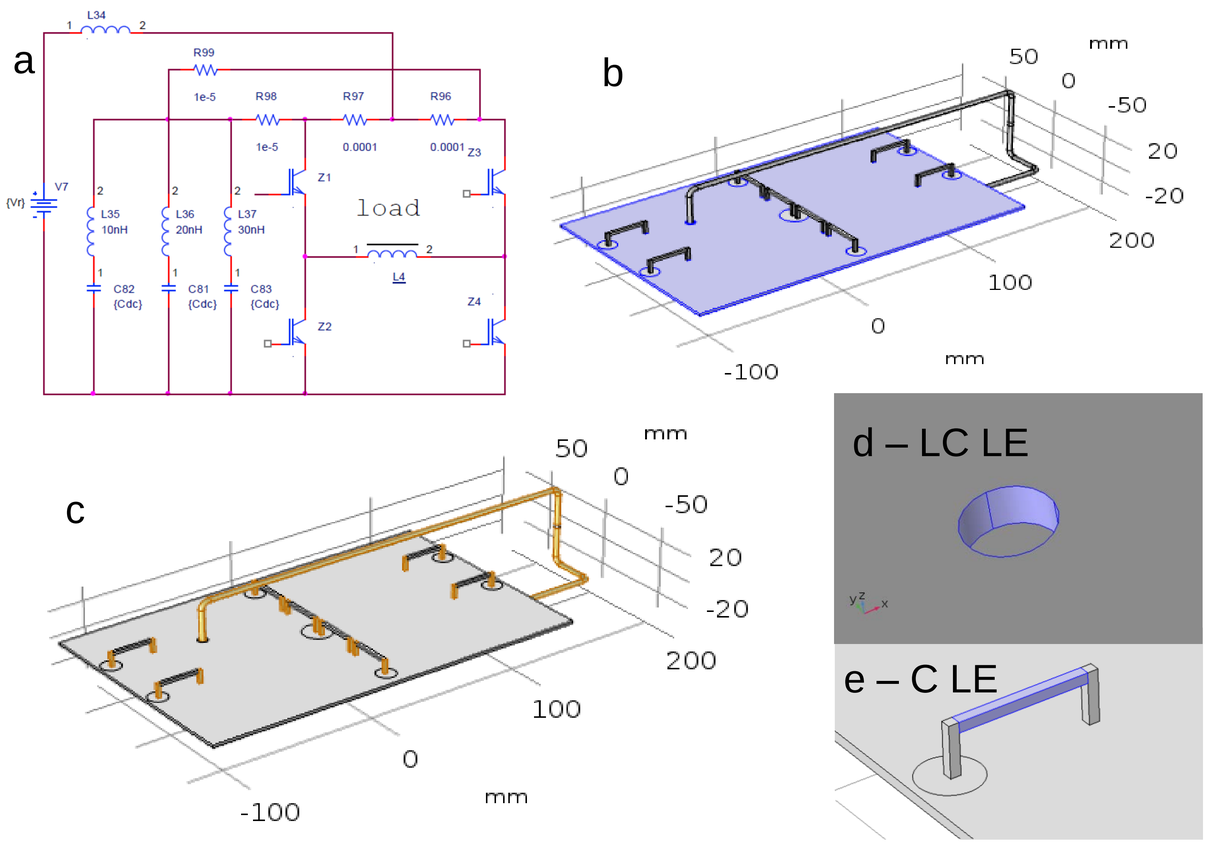

Figure 3. a - H-bridge simulation circuit (simplified), b - TBC; c - IBC, d, e –each capacitor pair modeled by cylindrical Lumped Element (LE5 shown), and in volume (same LE5 shown), respectively. Current fed via Lumped Port.

RESULTS:

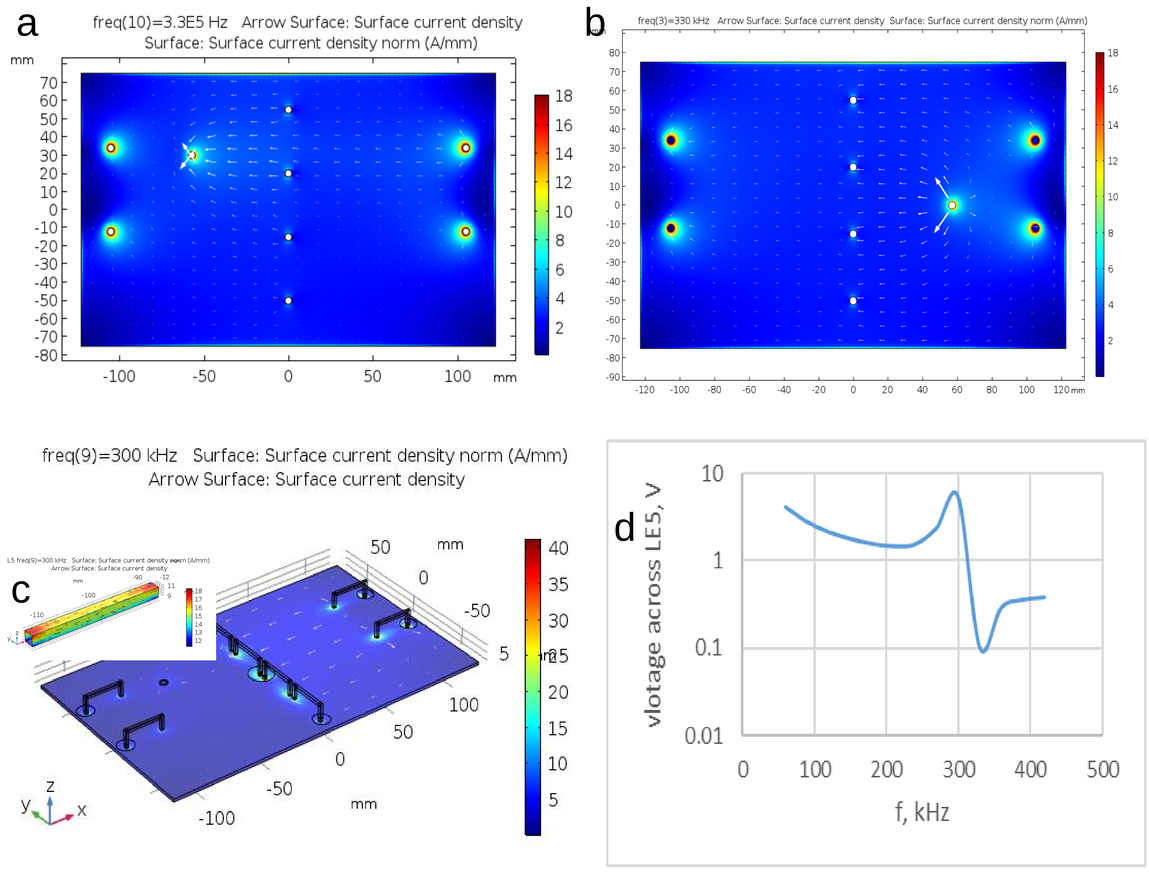

Figure 4. a, b – surface current density of top and bottom plates, respectively, at 330 kHz (LC-LE). c - surface current density C-LE. d - voltage across LE5 vs frequency.

Table 1. Copper plates losses for both handlebar and dot (cylinder) capacitor models. ACCURACY VERIFIED IN BENCHMARKING 2-D SIMULATIONS.

	Handles (C-LE)	Cylinders (LC-LE)
freq (kHz)	Surface loss (W)	Surface loss (W)
120	3.5603	3.34
180	3.5206	3.45
240	4.215	3.59
300	88.114	4.11
330	9.1919	60.73
360	4.7929	5.08

CONCLUSIONS: Simulation accuracy using TBC is acceptable in pertinent frequency range. Analyses showed that busbar can be designed on the base of usual PCB without resorting to costly heavy copper. Future work will add thermal simulations in pulsed modes typical for Computer Tomography applications, improved layout, and collecting experimental data on current sharing and thermal cycling.

REFERENCES:

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