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Compact 2kV IGBT Modules for Cascaded Static Var Generator

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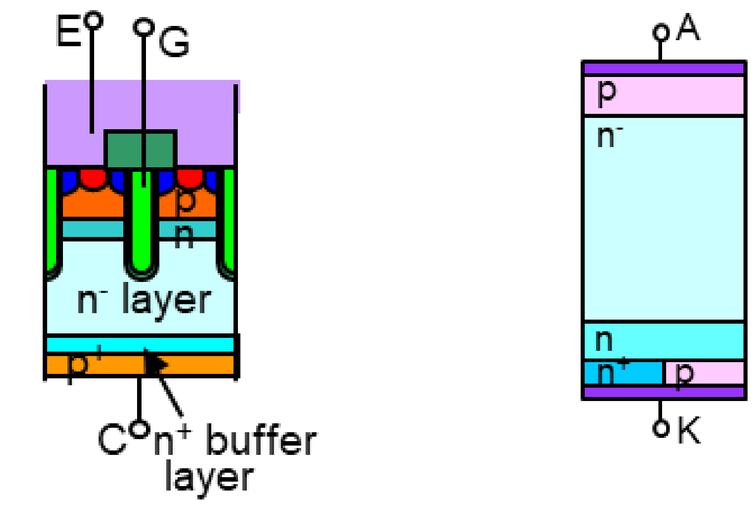
1. Introduction

To simply the design of DC1500V power conversion system and reduce the power consumption, Mitsubishi Electric developed LV100–package IGBT module CM1200DW–40T. The outline is as Fig.1.

Fig. 1. LV100–type T–series 2.0kV IGBT module

CM1200DW–40T adopts 7th generation IGBT technology with CSTBT™3 structure, which can be seen as Fig.2(a), thinner N– drifter layer was used to realize lower power loss. Meanwhile, the dv/dt controllability in switching becomes easier when changing R_G value. RFC (Relaxed Filed of Cathode) diode technology was applied as Fig.2(b), P layer is partially added on the cathode side, so holes are injected at the timing of reverse recovery, which can suppress the rise of steep recovery voltage and avoid snappy recovery.



(a) IGBT chip (b) FWD chip

Fig. 2. chipsets

Industrial LV100–type package adopts a novel structure with IMB (Insulated Metal Baseplate), as shown in Fig.3, the insulation layer and baseplate are integrated, eliminating the conventional solder layer under substrate, so there's no solder delamination issue caused by thermal strain. The lifespan which is caused by system stop and start is prolonged.

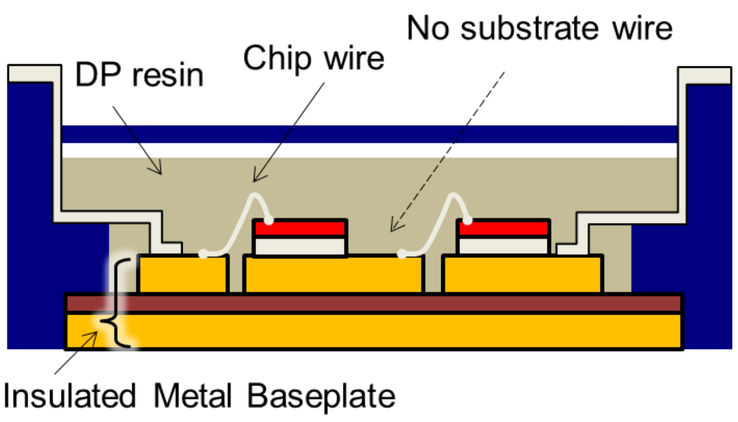


Fig. 3. Internal structure

2. Cascaded SVG

A typical topology of cascaded large–capacity SVG is as Fig.4, three phases connect in Y–style, and each phase connects the grid with a reactor. Each phase is composed of multiple power units, which adopt H–bridge, each power unit can output 3 levels, if N sets of power units connects in series, the output voltages are superimposed to form 2N+1 level.

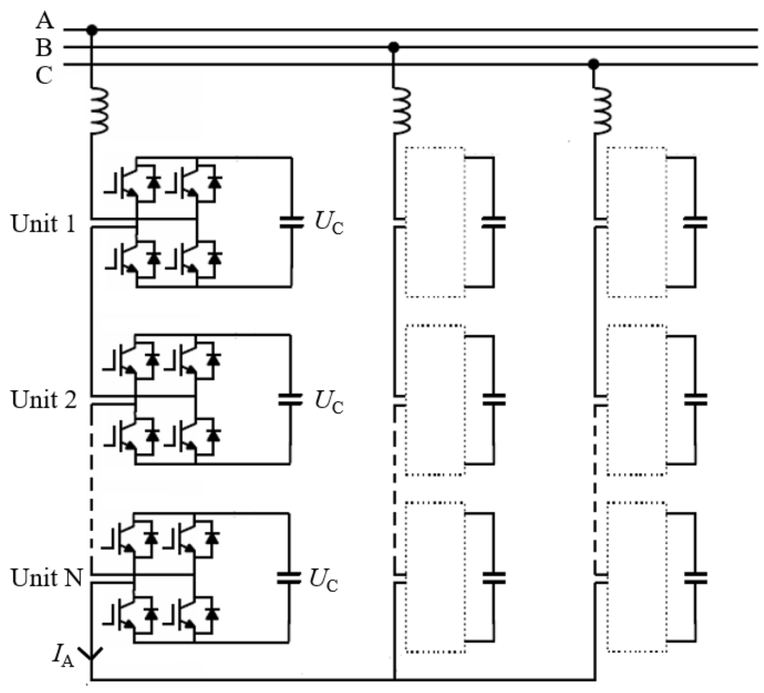


Fig. 4. Cascaded SVG topology

Currently, for the cascaded SVG, 1.7kV IGBT modules are usually selected. Based on the power ratings, 75A, 100A…600A IGBT modules are chosen accordingly. Here we take 35kV/50MVar SVG for example, the rated current I_O=825A, in this case, NX–package 1.7V/600A IGBT 2–paralleling is required, but for CM1200DW–40T, no need paralleling.

Table. 1. IGBT solutions for 35kV/50MVar

	Conventional IGBT solution	New IGBT solution
IGBT outline		
IGBT paralleling	2para	no
Voltage	1.7kV	2kV
Current	600A	1200A

3. Comparisons of different IGBT solutions

2kV LV100 IGBT has a higher operation voltage than 1.7kV NX IGBT, so the cascaded quantity of power units could be reduced, by calculation, if we improve the DC voltage 50% for each power unit, the cascaded power unit quantity reduces from 36 sets to 24 sets, which could decrease 1/3.

Table. 2. DC voltage and power unit comparison

35kV SVG	Use 1.7kV NX IGBT	Use 2kV LV100 IGBT
DC voltage of power unit	1kV	1.5kV
Cascaded power unit quantity (for one phase)	36	24

If we consider the whole SVG system, as in Fig.5, the total power units decrease from 108 sets to 72 sets, and the total IGBT quantity reduces from 432pcs to 144pcs, which decrease 2/3. Both power units and IGBT modules can be decrease a lot, which is in favor of cost and dimension of SVG.

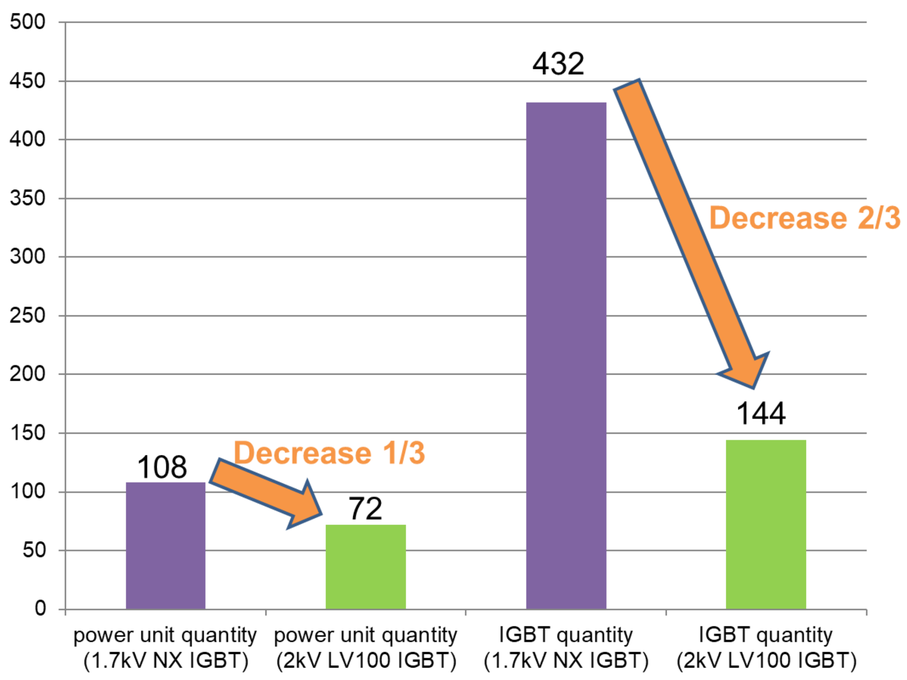


Fig. 5. Comparison of different IGBT solutions

For proposed 35kV/50MVar SVG, the working conditions: Vcc/Io=1000V/412.5A (for 1.7kV/600A NX IGBT), 1500V/825A (for 2kV/1200A LV100 IGBT), fs=500Hz, fo=50Hz, PF=0, Modulation ratio=1, Rg=1Ω. The IGBT power loss comparison is as Table.3.

Table. 3. DC voltage and power unit comparison

Power loss	1.7kV/600A NX IGBT	2kV/1200A LV100 IGBT
IGBT DC loss	195.8W	417.85W
IGBT switching loss	51.47W	231.19W
Diode DC loss	220.62W	414.55W
Diode switching loss	14.22W	62.01W
Total loss (1 module)	964.22W	2251.24W

Considering the total IGBT losses in the whole SVG system, the power loss comparison can be seen in Fig.6. The total IGBT power loss decreased 22% for 2kV LV100–package IGBT solution.

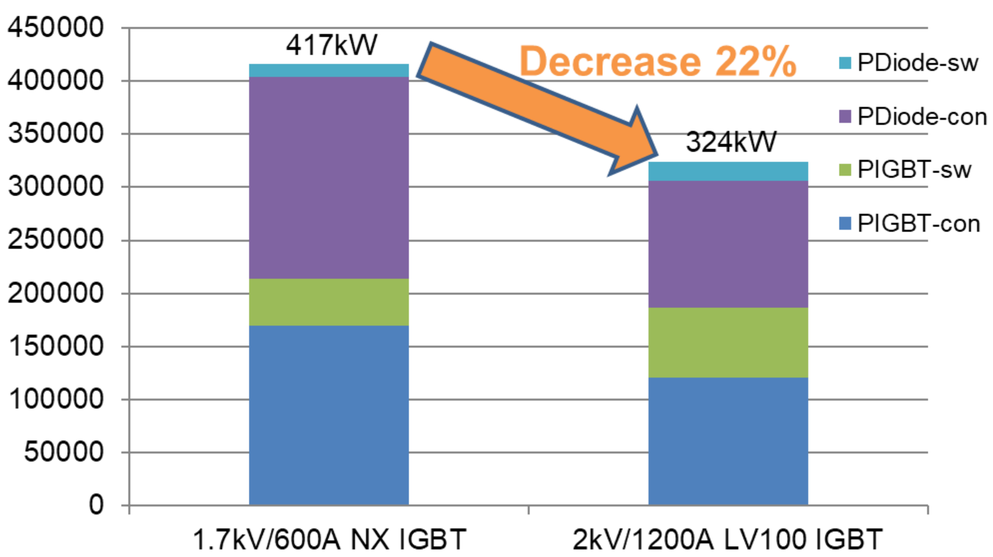


Fig. 6. Comparison of total IGBT power loss

4. Experimental results

To verify the switching characteristics of CM1200DW–40T, we take the Double Pulse Test (DPT). I_C =1200A as DPT testing current and V_{CC} =1500V as DPT testing voltage, V_{GE}=15V/–10V, no snubber capacitor, Tj=25℃.

The turn on waveform is as Fig.7. The turn off waveform is as Fig.8. The peak voltage at turn off is 1787V, which has more than 200V margin to the breakdown voltage 2kV. Meanwhile, we can see the stable operation at V_{CC} =1500V and no oscillation occurrence.

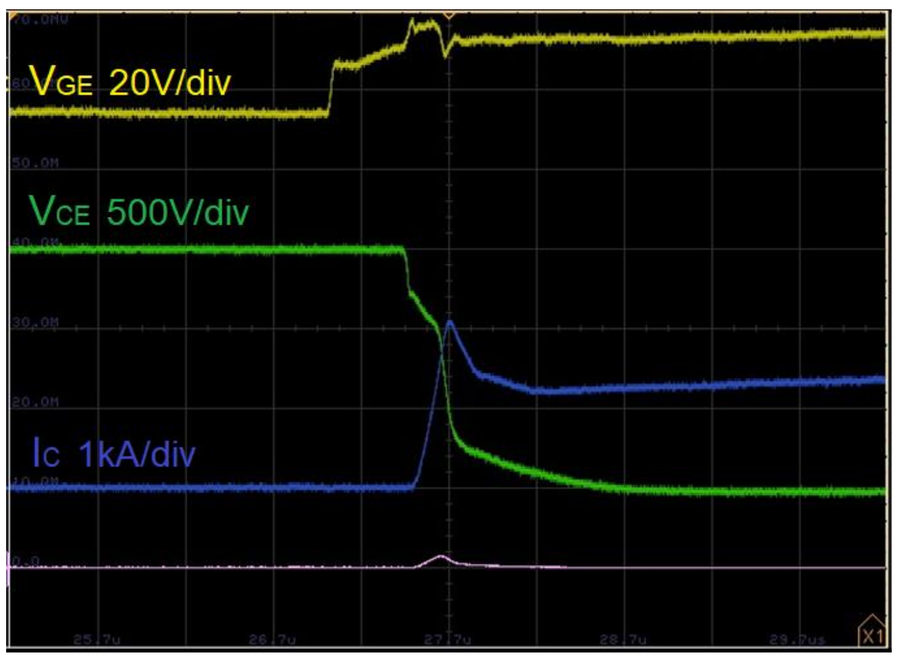


Fig. 7. CM1200DW–40T turn on waveform

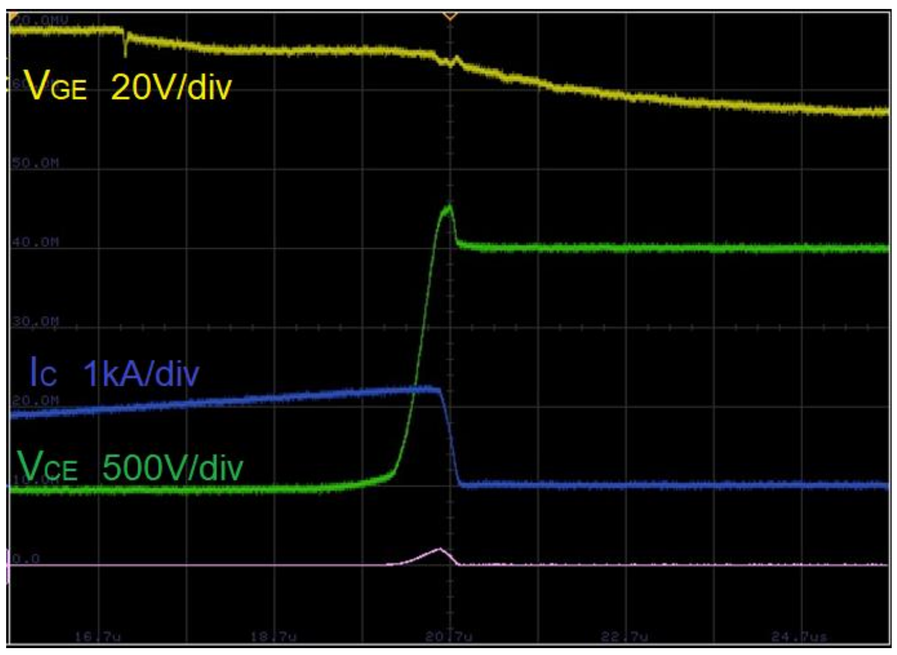


Fig. 8. CM1200DW–40T turn off waveform

5. Conclusion

The paper introduced Mitsubishi Electric 2kV LV100–type IGBT module CM1200DW–40T.

Two different IGBT solutions for Cascaded SVG were compared in detail. Compared to conventional 1.7kV NX–package IGBT module, 2kV LV100–package IGBT module can shrink the power unit volume by around 20%, reduce the quantity of cascaded power units by 1/3, and decrease the total IGBT power loss could by 22%, which could bring downsizing, high current density, and high efficiency for Cascaded SVG system..

At last, based on the proposed SVG working conditions, double pulse test was done to verify the switching characteristics.