M-2-01 (Invited) Extended Abstracts of the 2019 International Conference on Solid State Devices and Materials, Nagoya, 2019, pp503-504

Imbalanced Voltage Analysis of Series-connected Active Power Semiconductor Devices Method in Power Electronics Systems for Automotive Applications

Masayoshi Yamamoto [a)]

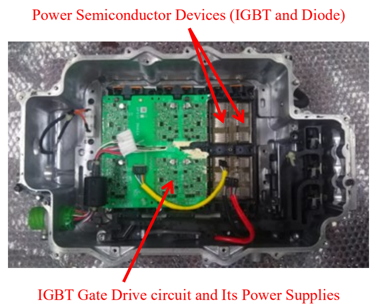
[a)] Institute of Materials and Systems for Sustainability, Nagoya University

Abstract: Wide band-gap semiconductor devices, such as: Gallium Nitride (GaN) and Silicon Carbide (SiC), have been attracted great interest from the automobile application area. However, the wide band-gap semiconductor devices are still too expensive to apply to power electronics system in automotive applications. In this application, the series-connected active power semiconductor devices method using low voltage rating power semiconductor devices of power conversion system is effective solution for the cost and efficiency problem. However there is no discussion about imbalanced voltage phenomenon for the proposed method. In this paper, the imbalanced voltage phenomenon has been analyzed and evaluated using simulation and experimental setup in case of hard switching DC-DC converter and soft switching one suitable for automotive applications.

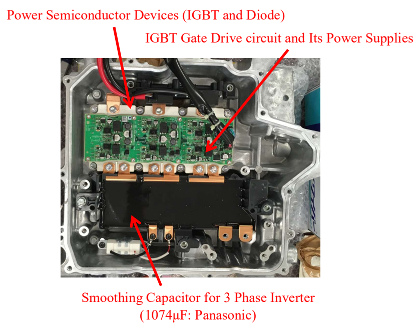
Keywords: Series-connected active power semiconductor devices method, automotive application

1. Introduction

Wide band-gap semiconductor devices, such as: Gallium Nitride (GaN) and Silicon Carbide (SiC), have been attracted great interest from the automobile application area. Because the electrical drive train with SiC and GaN power semiconductor devices can improve its efficiency as compared with the usual Si-IGBT devices. This means that the Hybrid Electric Vehicle using the electric drive train with SiC and GaN devices can achieve significantly improved fuel economy. However, the wide band-gap semiconductor devices are still too expensive to apply to power electronics system in automotive applications. The evolution of power semiconductor device in Electric Vehicle (LEAF: Nissan Motor Co., Ltd.) is shown in Fig. 1[1]. The first model of LEAF has been applied the custom-made power semiconductor module package. On the other hand, the second model is applied function common power module (FS800R07A2E3: Infineon)[2]. Therefore, this figure means that the cost of power semiconductor will decrease in automotive application. To solve the problem, the series-connected active power semiconductor devices method using low voltage rating power semiconductor devices of power conversion system have been improved from the cost and low loss performance points of view[3]. However, imbalanced voltage phenomenon occurs in the series-connected active power semiconductor devices method in case of not only hard switching



(a) Inverter of 1st model in LEAF



(b) Inverter of 2nd model in LEAF

Fig. 1 Evolution of EV inverter.

power conversion system but also soft switching one. In this paper, imbalanced voltage mechanism in each power semiconductor device have been analyzed and the cause of imbalanced voltage phenomenon in series-connected method extracted in Boost chopper for electric vehicle motor drive applications. Furthermore, imbalanced voltage phenomenon in series-connected method in case of soft switching DC-DC converter have been evaluated using experimental setup and the novel control method for the imbalanced voltage in each power semiconductor devices in case of soft switching DC-DC converter.

2. Analysis of Series-connected Power Semiconductor Devices Method in Hard Switching

Fig.1 shows the boost chopper circuit selected for this analysis. And each parameter of power semiconductor device has been defined as illustrated in Fig.2. Analyzed the influence of each parameter of power semiconductor device of series-connected method in condition of 500W boost chopper (input voltage V_I=100 [V], output voltage V_o=200 [V], switching frequency f_s=50 [kHz]), the result is indicated in Fig.3. From this result, the threshold voltage of power semiconductor device has great influence on imbalanced voltage phenomenon in series-connected method.

3. Analysis of Series-connected Power Semiconductor Devices Method in Soft Switching

Evaluation target of soft switching DC-DC converter is shown in Fig. 5. LLC converter is

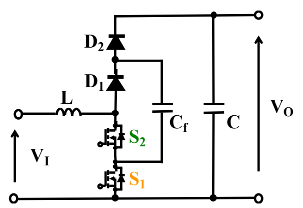


Fig. 2 Boost Chopper Circuit.

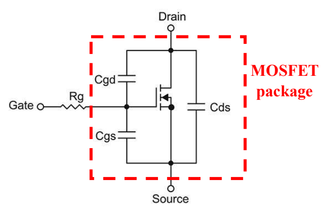


Fig. 3 Each parameter of power device.

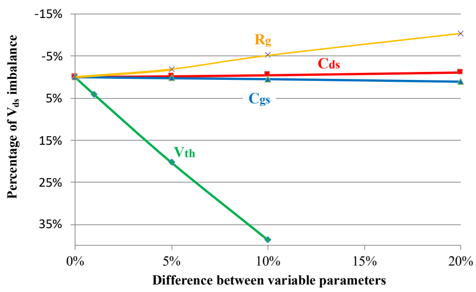


Fig. 4 Analyzed result.

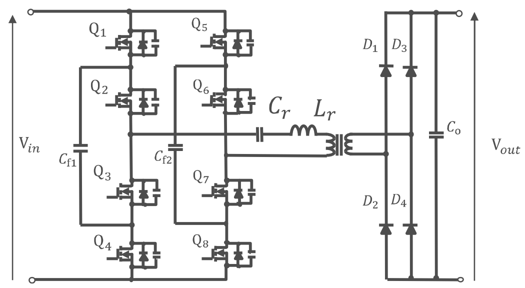


Fig. 5 Series-connected method LLC converter.

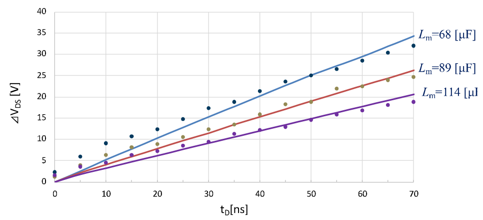


Fig. 6 Evaluated result.

selected for the evaluation for control of each voltage across the power semiconductor devices. Using 120W LLC converter (input voltage V_{IN}=40 [V], output voltage V_{out}=19 [V], switching frequency f_s=84 [kHz]), it is clear that the parameter design of soft switching converter can control the voltage balance performance from the evaluation result.

4. Conclusions

The study has clearly confirmed the fact that the voltage balance performance mainly depends on threshold voltage of active power semiconductor device. This means that the voltage balance depends on production line quality of semiconductor device in case of hard switching scheme. On the other hand, it can be concluded that the design of circuit parameter can control the voltage balance performance in case of soft switching scheme. Therefore, the result obtained show that the series-connected method is good compatible with soft switching scheme.

References

[1] NISSAN LEAF Web Catalog”, , (www3.nissan.co.jp/vehicles/new/leaf.html).

[2] Infineon Technical Information”, , (www.galco.com/techdoc/eupc/fs800r07a2e3_dat.pdf).

[3] M. Schweizer., T. B. Soeiro, " Heatsink-less Quasi 3-level Flying Capacitor Inverter Based on Low Voltage SMD MOSFETs," Record of EPE'17 ECCE Europe.