The Investigation on the Converter Applied to Low-Speed Maglev

Lan Zhiming and Li Yaohua

Key Laboratory of Power Electronics and Electric Drive, Institute of Electrical Engineering, Chinese Academy of Sciences, Graduate University of the Chinese Academy of Science, P.R.China

lanzhm1979@163.com

Li Chongjian, Li Fan, Duan Wei, Yang Qiongtao and Wang Chengsheng

Automation Research and Design Institute of Metallurgical Industry, P.R.China

ABSTRACT: In this paper a two-level converter based on IGBT is proposed. The converter can be applied to driving the low-speed maglev. It mainly includes DC voltage input breaker, DC capacitor and three-phase inverter based on IGBT. The converter is placed on the low-speed maglev. The power grid supplies the DC voltage source for the converter. The pre-charge resistor is used in the converter to limit the charge speed. When the DC capacitor is charged to the power gird DC voltage the pre-charge resistor is short circuited by a breaker. The DC voltage source can be converts to AC power by the converter to drive the low speed maglev. The capacity of the converter can reach 1MVA.

1 INTRODUCTION

Maglev technology has been emerged for several decades. The high-speed maglev commonly means the velocity of the maglev is higher than three hundred kilometers per hour. It can be applied into long distance traffic. In Shanghai, China a commercial operation line of high-speed maglev has been in operation for several years. The low-speed maglev commonly means the velocity of the maglev is lower than one hundred kilometers per hour. It can be applied into short distance traffic, for example the city traffic.

In this paper a two-level converter based on IGBT is proposed. The converter can be applied to driving low-speed maglev. The topology of the converter is introduced. The IGBT modules used in the converter are medium voltage and large current device modules. The switch characteristic of IGBT device used in the converter is analyzed, especially the influence of the snubber circuit on the turn-off characteristics of IGBT module is also analyzed by simulation in PSIM software. The converter is developed. The experiments of the converter is carried out and the results show that the converter meet the design requirements.

2 THE TOPOLOGY OF THE CONVERTER

In this paper a two-level converter based on IGBT is proposed. The converter can be applied to driving the low-speed maglev. The topology of the converter is shown in Figure 1. It mainly includes DC voltage input breaker, DC capacitor and three-phase inverter based on IGBT. The converter is placed on the low-speed maglev. The power grid supplies the DC voltage source for the converter. There are two input breaker: pre-charge breaker and main breaker. At first the two input breaker are both open. When control system gives out the charge signal the pre-charge breaker is closed. The power grid charges the capacitor through pre-charge resistor. The pre-charge resistor is used in the converter to limit the charge speed. When the DC capacitor is charged to the power gird DC voltage the main breaker is closed and the pre-charge breaker is open so that the pre-charge circuit is short circuited by main breaker. The DC voltage source can be converted to three phase AC power by the converter to drive the low speed maglev. There are three phase output RC filter circuit on the output end. With air cooling condition the capacity of the converter can reach 1MVA.

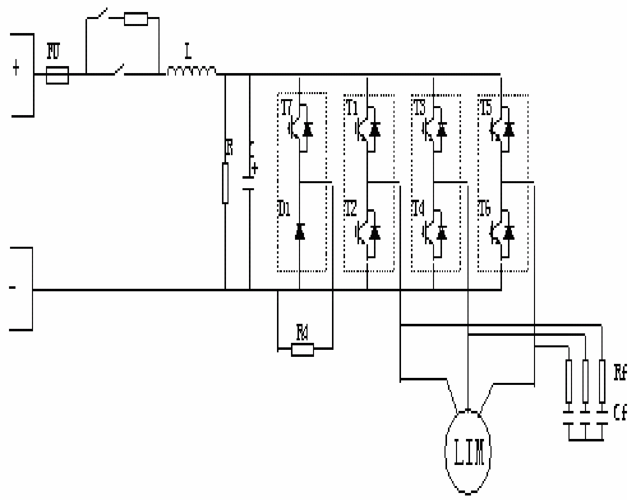


Figure 1. The topology of the converter based on IGBT I

There are a lot of types of snubber circuit used in converters based on IGBT devices [1][2]. The Figure 2 shows three types of them commonly used. The power loss of (a) type and (b) type snubber circuit is larger so that they are rarely used in large capacity and high frequency converter. The power loss of (c) type snubber circuit is smaller than the two type mentioned above. The medium voltage and large current IGBT devices are used in the converter this paper proposed so that the (c) type snubber circuit is adopted for its excellent performance.

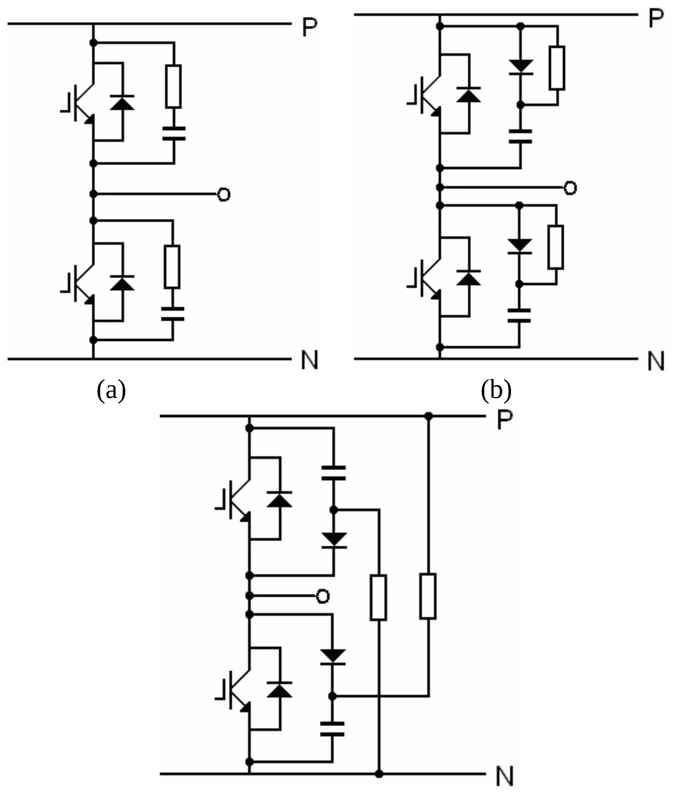


Figure 2. The sunbber circuit of converter based on IGBT

3 TURN-OFF CHARACTERISTIC OF IGBT USED IN THR CONVERTER

The IGBT device module used in this converter has large di/dt due to its fast switching speed, which can cause the overshoot voltage on wiring stray inductance in the main circuit of the converter when an IGBT module is turned off [3]. So the converter needs snubber circuit. The simulation model of this converter considering stray inductance is set up in PSIM software to research the influence of the stray inductance and snubber circuit on the turn-off characteristic of IGBT, as shown in Figure 3. The dc voltage is 750V, the turn-off current is 1000A. There are two main stray inductance in this converter is considered: the stray inductance L_{st} in dc bus and the stray inductance L_{sn} in snubber circuit, as shown in Figure 3 below.

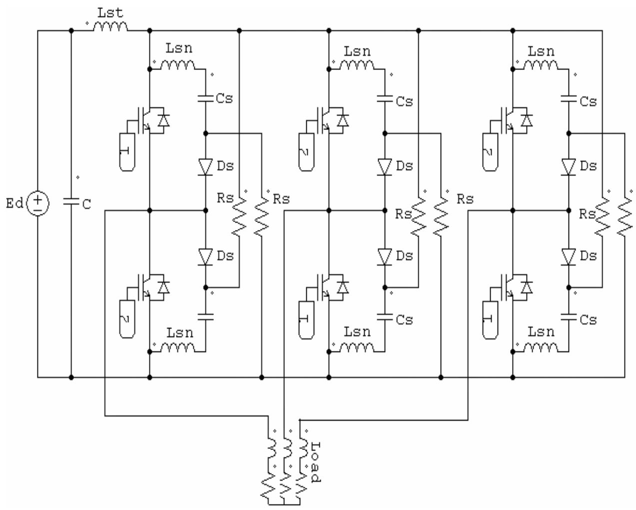
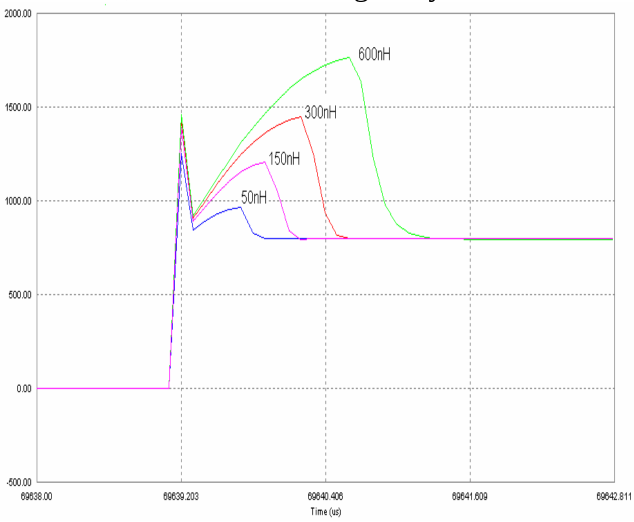
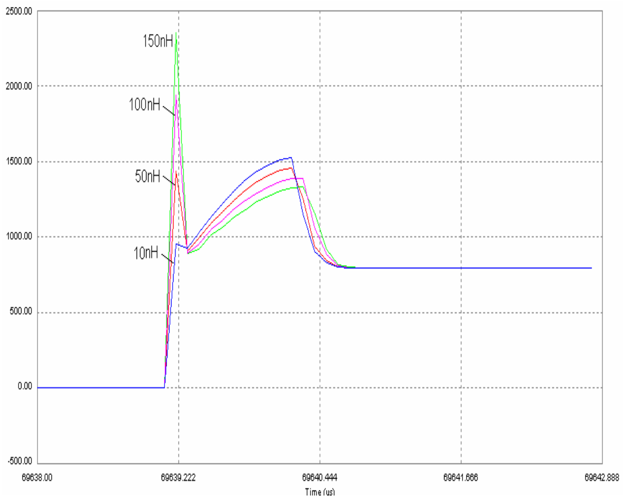


Figure 3. The simulation circuit set up in PSIM software

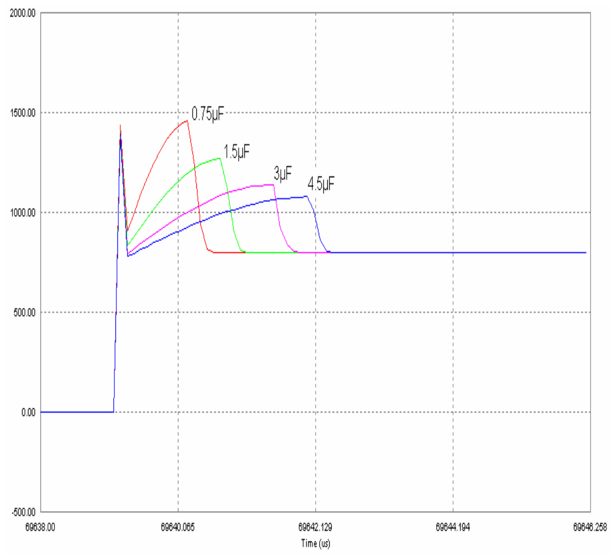
The simulation results are shown in Figure 4 below. The Figure 4-(a) shows the influence of stray inductance L_{st} on the turn-off characteristic of IGBT. With same turn-off current, the stray inductance L_{st} is larger, the second peak of turn-off voltage of IGBT is larger, but the first peak almost does not change. The Figure 4-(b) shows the influence of stray inductance L_{sn} on the turn-off characteristic of IGBT. With same turn-off current the stray inductance L_{sn} is larger, the first peak of turn-off voltage of IGBT is larger, but the second peak almost doesn't change. The Firgure 4-(C) shows the influence of C_s in snubber circuit on the turn-off characteristic of IGBT. With same turn-off current the C_s is larger the second peak of turn-off voltage of IGBT is smaller and the first peak of turn-off voltage doesn't change. The Figure 4-(d) shows the influence of R_s in snubber circuit on turn-off characteristic of IGBT. The R_s is smaller, the second peak of turn-off voltage of IGBT is smaller. But if R_s is too small, the turn-off voltage maybe vibrate.



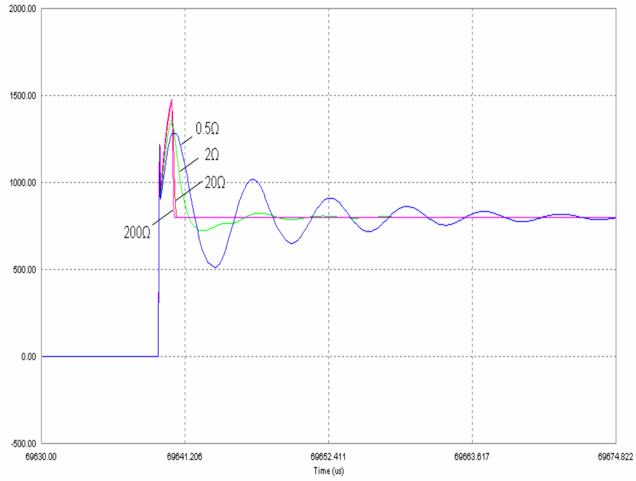
(a) The influence of stray inductance L_{st}



(b) The influence of stray inductance L_{sn}



(c) The influence of C_s in snubber circuit



(d) The influence of R_s in snubber circuit

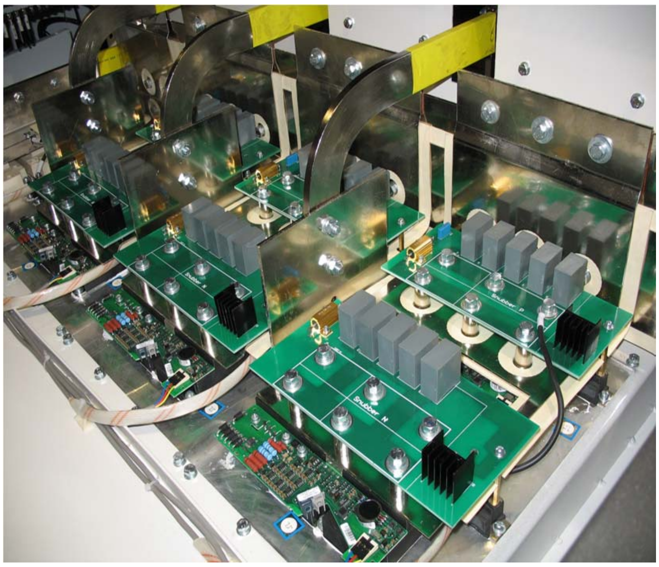
Figure 4. The simulation results of research on turn-off characteristic of IGBT

Through the research we can see that the stray inductance in the converter bring bad influence on turn-off characteristic of IGBT, so we need choose reasonable snubber circuit to restrain the influence of stray inductance. Through optimized structure design the stray inductance can be reduced greatly. In some converter produced by international electrical corporations the stray inductance is very small so that there are no snubber circuits.

4 THE CONVERTER AND EXPERIMENTS

The pictures of developed converter are shown in Figure 5. There are two cabinets. There are input and output bus, input main breaker and pre-charge circuit, input reactor in one cabinet. The main power inverter circuit and chopper circuit of the converter are in the other cabinet.

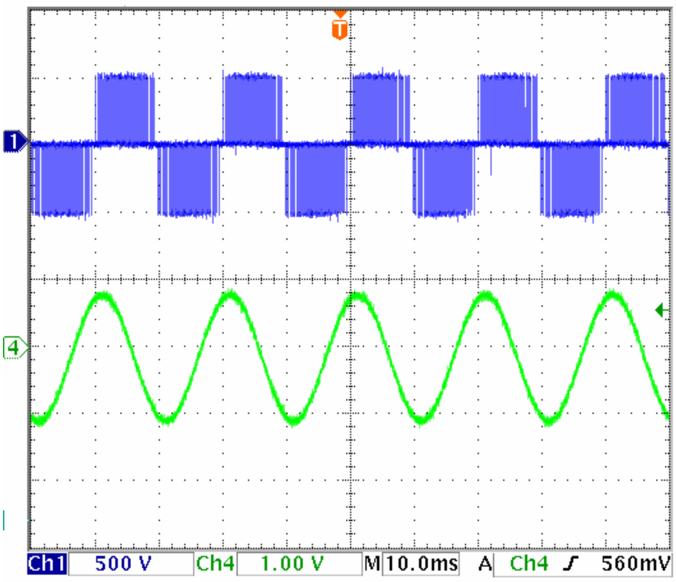
(a) Two cabinet of the converter



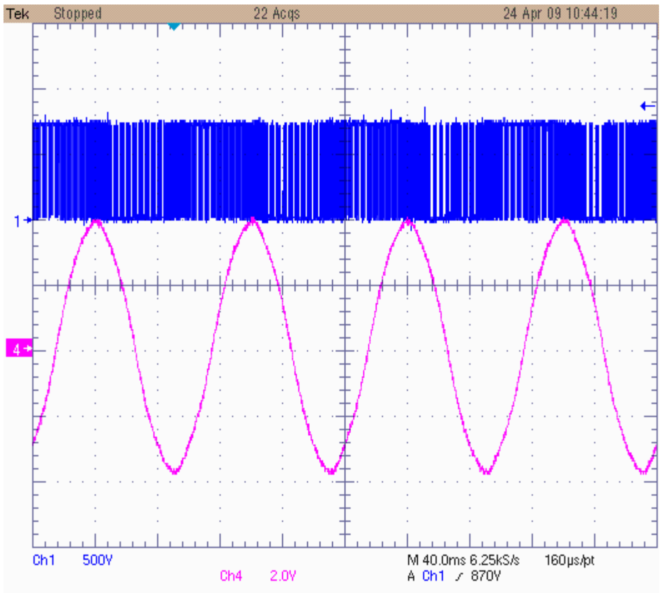
(b) The picture of inverter cabinet

Figure 5 The pictures of the converter

We took the three phase 2mH reactor as the load of the converter. In the experiments the output frequency is a fixed value. The converter adopts SVPWM modulation algorithm. We alter the modulation index to alter the output current. The experiment result waves of the converter are shown in Figure 6. The dc voltage is 500V and the output line voltage and current waves is shown in Figure 6-(a). The maximum of output current is about 500A. The Figure 6-(b) shows the output phase voltage and output current. The dc voltage is 750V and the maximum output current is 2000A. The modulation index is about 0.8. The output capacity of the converter reaches 1 MVA.



(a)



(b)

Figure 6. The experiment results of the converter

5 CONCLUSIONS

We have successfully developed a converter which can be applied to driving low-speed maglev. The turn-off characteristic of IGBT is investigated. The experiments of the converter with reactor load are performed and the results showed the converter reaches the design requirements. Now in Beijing, China there is a low-speed maglev line is going to be built. The low-speed maglev will get development in city traffic.

6 REFERENCES

W. M, “Efficient Snubber for Voltage source GTO Inverter”, IEEE Transactions on power electronics. 1987, (3):264 ˜ 272.

Tore U., “A Snubber Configuration for Both Power Transistors and GTO PWM Inverters”, PESC’84, 1984:42 ˜ 53.

Chokhawala R., Catt J., Pelly B., “Gate Drive Considerations for IGBT Modules”, IEEE Transactions on Industry Applications. 1995, 31(3):603~611.