REACTIVE CURRENT COMPENSATING DEVICE FOR HIGH-FREQUENCY TRANSFORMER

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ABSTRACT

Recent years, inverter driven motor is widely used in many field including the home appliances and EV (Electric Vehicle). In this driving motor, the rising time on the output side of the switching operation is shortened to 50ns~2μs, and high voltage including high frequency component of the 100Hz~10MHz called inverter surge occurs. In an electric vehicle, most motor-driven voltage is 450V. This PWM voltage waveform is superimposed on a surge. The temperature rose by high load operation, and PDIV (Partial Discharge Inception Voltage) goes out easily with the low voltage. From these backgrounds, the nondestructive-test as well as design and experiment of the partial-discharge-test container which corresponds to high frequency had been done. In this research, we have made the testing transformer (5kHz~50kHz) for high frequencies. As a result of the FRA (Frequency Response Analysis) test, there was reactive current flows in 10kHz~60kHz. It shows the technical problem that the testing-transformer hadn't functioned. In this study, we will report the development, the design and the operation-test of the reactive-current compensating device as a suggest solution.

1. INTRODUCTION

Inverter driven motor is widely spread in EV and consumer electronics products. But the inverter is referred to cause the overvoltage or noises called Inverter Surge with switching. At the same time, with the motor getting smaller and larger, the demand of the compact insulation design gets more important. To maintain the reliability of insulation, the detection method of the winding dielectric breakdown portion had been asked for [1]-[6] . With these, we tried the research of the non-destructive test with the equipment corresponding to the high frequency, such as the high voltage frequency partial discharge tester. The partial discharge test used a twisted pair in the pseudo-winding of motor and the transformer boosting in the high frequency power.

The reactive current occurred by increasing the frequency because of the influence from the stray capacitance of transformer and motor[7] . It leads to the loss of power. Before this paper, we already know the current of the stray capacitance could be changed by changing the frequency. In this way, we designed this device to make the sample L controllable to compensate for the reactive current.

2. DESIGN OF HIGH FREQUENCY TRANSFORMER

The transformer was used in this study that the frequency band in the high-frequency power source is 5 kHz ~ 50kHz, the output voltage is 5kVrms, and the capacity is 200VA. The specification of this transformer is shown in Table 1.

Table 1 Transformer specification

Body	Frequency	5 kHz～50 kHz
	Output Voltage	7071V(5 kVrms)
	Capacity	200 VA
Core	Material	PC40(TDK)
	Name	PQ-107
	Effective cross – section	1428mm^2
	AL-Value	5000 nH/N^2
	Maximum magnetic flux density	300 mT
Primary winding	Material	PEW
		Φ0.33 mm×19T
	Turns	7 T
	Cross-sectional area	3.14 mm^2
	Length of the winding	2.1 m
	Internal resistance	11mΩ
	Conductor diameter	Φ0.3 mm
	Conductivity	0.0172 Ωmm^2/m
Secondary winding	Material	Φ0.33 mm
	Turns	749T
	Length of the winding	141.2 m
	Conductor diameter	Φ0.3 mm

3. FREQUENCY CHARACTERISTICS OF THE HIGH-FREQUENCY TRANSFORMER

3.1 FRA（Frequency-Response-Analyzer）test

The FRA test of high-frequency transformer was carried out with the Aglient4294A. It has input voltage 500mV applied to the primary side of the transformer. Test circuit is shown in Figure 1.

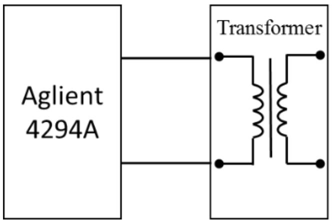


Fig.1 FRA test circuit

3.2 FRA test results

The result of this FRA test is shown in Figure 2.For working an impedance measurement, there have measured whether the current flowed in reactance and capacitance.

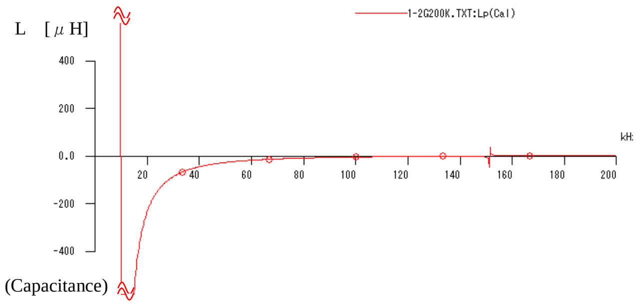


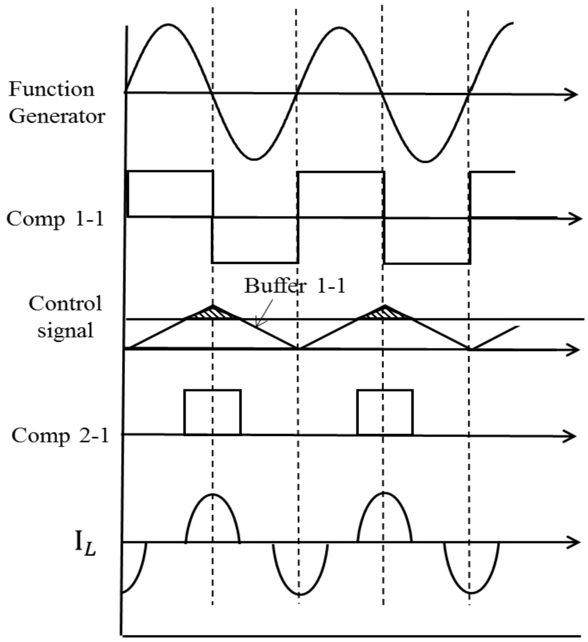
Fig.2 FRA test waveform

From Figure 2, we can confirme the loss was increased in the range of frequency from 10kHz to 60kHz. The current through the transformer looks like a Capacitance. So, it’s necessary to suppress the reactive current by compensating device.

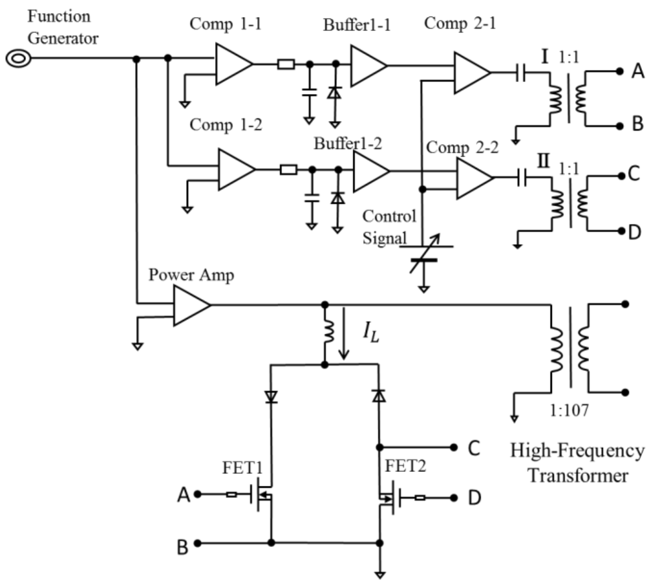
4. DESIGN OF THE REACTIVE CURRENT COMPENSATING DEVICE FOR HIGH-FREQUENCY TRANSFORMER

Figure 3 shows the equipment appearance. Figure 4(a) shows the image waveform of each point (From in-put Comp1-1 to out-put Comp2-1). And the circuit of this designed device is made from Figure 4(b).

Fig.3 Equipment appearance



(a) Image waveform



(b) Block Diagram

Fig.4 Reactive current for high-frequency transformer compensating device

Table 2 Operating principle

Point	Explain making waveform
Comp1-1 (Comp1-2)	Input the sine wave signal and output rectangular wave signal.
Buffer1-1 (Buffer1-2)	Make the input-waveform become the triangular wave by the integration circuit.
Control Signal	Make the waveform the threshold.
Comp2-1 (Comp2-2)	Compare the output waveform of Buffer1-1 with Control Signal which as the threshold. Pick out a higher part than Control Signal and output the shaded area.

From Figure 4, the movement of each point as shown in Table 2.

The signal wave from Comp2-1 is input to the Ⅰ Figure 4(b), raise the voltage and input them to MOSFET. FET1 switched each output-signal (up and down) into the L, make the waveform I_L to control the reactive current.

5. DEVICE OPERATION CHECK TEST

Input the sine wave of 1V from Function Generator (F.G.) to Comp1-1. Also input ±12V for driving IC with 2 DC power supplies. As operation check, it was measured for 2 points as following.

5.1 Measure the each operation waveform in Comp1-1 to Comp2-1

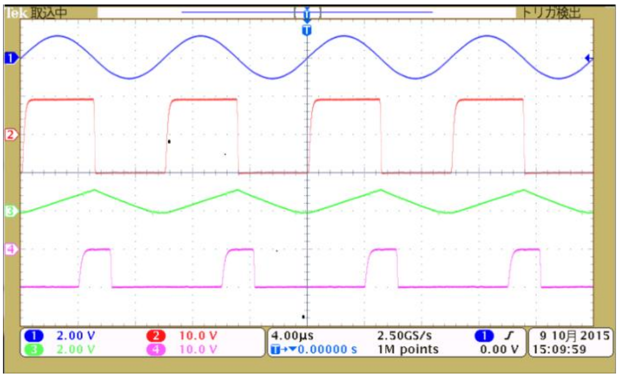
Lock the input-voltage and the frequency from Function Generator. Then measure the input-waveform from Function Generator, output-waveform of Comp1-1, Buffer1-1, and Comp2-1.

5.2 Measure the current waveform in L with changing frequency

Change the frequency from 25kHz to 50kHz with 1V input-voltage from Function Generator. And measure current waveform in L of Figure 4(b).

6. RESULT OF MEASUREMENT.

6.1 Each operation waveform in F.G. output waveform,Comp1-1, Buffer1-1, and Comp2-1.



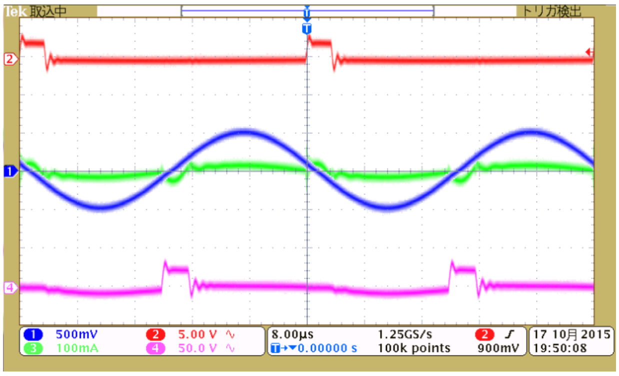
There is the operation waveform of the reactive current control device in Figure 5.

Fig.5 Operation waveform
(CH1: Input-waveform from F.G., CH2: Comp1-1, CH3: Buffer1-1, CH4: Comp2-1).

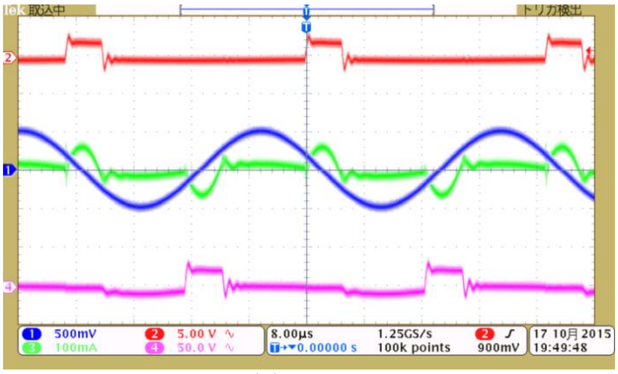
As the result, the device operated correctly as designed in Figure 4(a) and Figure 5. So we can make sure the device can do phase control for reactive current control by measuring the current waveform through L.

6.2 Current waveform I_L of each frequency (25kHz to 50kHz) in L

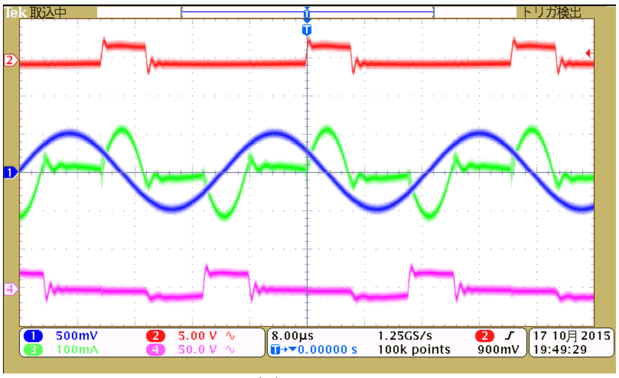
Figure 6(a)-(e) shows the current waveform I_L.



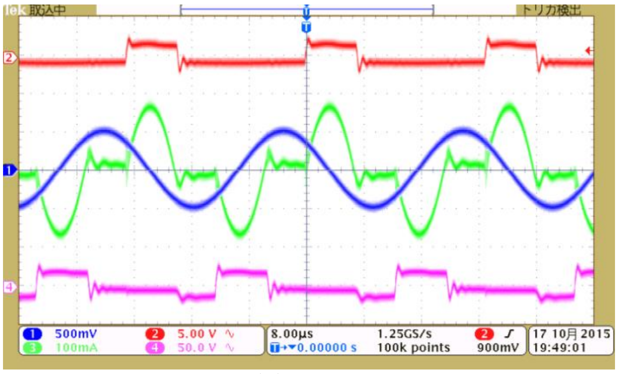
(a) 25kHz



(b) 30kHz



(c) 35kHz



(d) 40kHz

Fig.6 Phase engineered current waveform I_L
(CH1: Input waveform from F.G., CH2: Comp2-1, CH3: I_L, CH4: Comp2-2).

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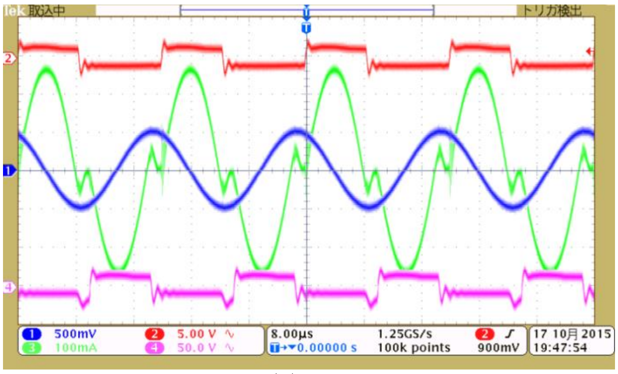

（e） 50kHz

Fig.6 (continue)

7. DISCUSSION

Changing the threshold voltage with the output voltage of the control signal, then the conduction width of Comp2-1 can be adjusted.Well, the threshold voltage is the average value from triangle wave of Buffer1-1.It outputs shaded area like Figure 4(a). It confirms the higher frequency, the lower threshold, and the higher current in L. As a conclusion from Figure 6(a)-(e), that is the higher frequency make the output current I_L larger. Here, the device operates correctly could be certified.

8. CONCLUSION

In this study, it’s successful to control the variable continuously phase at the frequency of L from 25kHz to 50kHz. Henceforth, the transformer or the power supply could control the reactive current with this device. It is planned to combine in transformer .

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