Technological Trend of Compact Pulsed Power Generators

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Power semiconductors have been applied to pulsed power generators, bringing new extent of capability in repetition rate, lifetime, compactness, and mobility to pulsed power sources. This development is accelerated in the last several years driven by the industrial applications such as excimer-laser excitation, flue-gas treatment, and accelerator power supply.

Keywords : compact pulsed power generator, MOS-FET, SITHy, semiconductor opening switch

1. Introduction

In the last two decades, pulsed power technologies have found various industrial applications such as material processing, laser pumping, flue-gas treatment, and waste disposal. In the same time, power semiconductor devices have made significant progress in both peak power and operation speed. Various semiconductor switching units using thyristors, IGBTs (insulated-gate bipolar transistors), and MOS-FETs (metal-oxide-semiconductor field-effect transistors) have become commercially available and have been used in various pulsed-power and power-electronics applications⁽¹⁾.

2. Examples of Compact Pulsed Power Generators

2.1 MHz Repetitive Pulsed High-voltage Generator Using MOS-FET High-speed switching units using MOS-FETs are considered to have potential applications in induction synchrotron and extensive studies are being carried out. It has been proved by previous experiments that the stacked MOS-FET units can switch under working voltage on the order of ~ 10 kV and current on the order of ~ 100 A, at the repetition rate of 1 MHz. In the same time, it has been found that the load impedance has strong influence on the switching speed of the MOS-FET unit. For example, a relatively large load resistance results in a longer turn-on or turn-off time of the switch. This effect is mainly caused by the residual capacitance of the switching device.

In order to obtain high-speed switching which does not depend on the load impedance, new type of MOS-FET switching unit was developed as shown in Fig. 1. Two groups of MOS-FETs, marked by FET(A) and FET(B) in Fig. 1, are controlled by opposite signals so that when one of them turns on, the other turns off. This operation can ensure fast switching of the voltage on the load. Typical result is shown in Fig. 2, which is obtained with load resistance of $2\text{ k}\Omega$.

2.2 Compact Pulsed Power Generator Using SITHy A new type of static-induction thyristor (SITHy) has been developed by NGK Insulators, Ltd. It is characterized by high power capability, fast switching, and long lifetime. Ultra-compact pulsed power generator that is aimed at automobile applications has been developed by using SITHy.

Figure 3 shows the photograph of this generator. It is designed

Fig. 1. Circuit diagram of MOS-FET switching unit

Fig. 2. Voltage waveform obtained on the load of the circuit shown in Fig. 1

Fig. 3. Pulsed high-voltage generator using SI-Thy

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Fig. 4. Circuit diagram of pulsed power generator shown in Fig. 3

Fig. 5. Circuit diagram of pulsed power generator using SOS

Fig. 6. Typical waveform of SOS current and output voltage on a 200 Ω

for automobile application and it uses a car-battery (12V DC) as the only power supply. The electrical circuitry is illustrated in Fig. 4. By two stages of inductive energy storage with opening switches, the 12V DC power supply of the battery is converted to 12 KV pulsed high-voltage output with pulsed width of 100 ns.

2.3 Semiconductor Opening Switch (SOS) and its Applications A relatively new type of solid switch, the semiconductor opening switch (SOS), is rapidly expanding its applications, especially for pulsed power generation by inductive energy storage. An SOS is a special kind of diode. It makes use of the carriers injected by the forward current to conduct a reversed current with limited time length. The abrupt cutoff of the reversed current is used as an opening switch.

We have developed a compact pulsed power generator using SOS. Its circuit diagram is shown Fig. 5. An IGBT is used as the initial switch, which transfers the stored energy in C_1 to C_2 through the transformer ST. During this time, a certain amount of carriers are injected into the SOS diode. When ST saturates, C_2 discharges and initiates a reverse current in the SOS. The SOS reverse current is suddenly cut off, generating a sharp output voltage pulse on the load.

Figure 6 shows the typical waveforms of the SOS current and the output voltage, obtained with load resistor of 200 Ω . The peak forward and reverse SOS currents are ~ 10 A and 110 A, respectively. The output voltage has a peak value of ~ 10 kV and pulsed width (FWHM) of ~ 25 ns.

3. Future Prospects

Driven by the rapidly expanding applications, the development of compact pulsed power generators is expected to progress at very high speed in the near future. Various new ideas of semiconductor-switching scheme and circuitry design will emerge and find their applications in material, environmental, medical, and biological fields.

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References

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