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Development of a 20 kJ Sparker for High Resolution Ocean Seismic Survey

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An ocean sparker with a stored energy of 20 kJ was developed for high resolution ocean seismic survey. The sparker is mainly composed of a high voltage high frequency charging supply, energy storage capacitors, a discharging switch and discharging electrodes. The H-bridge inverter and series resonant mode were adopted in the charging supply, and a dry high voltage transformer was used to improve the safety and maintenance, the average charging rate exceeded 4 kJ/s. An optical fiber connected between the high voltage system and the control system was used to isolate high voltage and transmit the high voltage signal. The high voltage electrodes of the discharging electrodes consisted of several hundreds of electrodes. The experimental results show that the sparker can be operated at repetition rates of 12 shots/min, and can meet the expected design requirements. Further field tests will be done in the near future.

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1. Introduction

In the 1960's, the sparker were introduced into marine seismic exploration. In China, the Institute of Electrical Engineering had developed high energy sparkers (maximum stored energy was 260 kJ) used for this application, stratigraphic profiles up to 10 km depths had been achieved in the Bohai Sea, and 6 sparker ships had been equipped from 1970's to 1980's [1, 2].

In recent years, with the development of ocean resources, high resolution seismic survey with a resolution of 0.5–2 m was required. The former technology is not suitable for this application any more. At present, there are several corporations working on the high resolution survey using sparkers such as Geo-Resources [3], AAE (in U.K.), Sigfrance (in France), etc., and the stored energy is between several hundreds joule to several thousands joule in most of the sparkers.

This paper presents a high energy sparker using high frequency high voltage inverter technology, long lifetime capacitors, solid state discharging switch and multi-tips electrodes technology.

2. Principle and system setup

2.1. Principle and circuit

When the stored electrical energy of a capacitor is discharged into a water gap through a discharging switch, it can generate tremendous shock waves and hydraulic waves to create seismic disturbance artificially. Usually we call it "electro-hydraulic effects". This technology can be used in many industrial applications. For the high resolution marine seismic survey, the negative high voltage multi-tip electrodes discharging technology is usually adopted. The multiple pressure pulse can be suppressed effectively and a relatively high acoustic frequency can be generated. A simplified circuit of the ocean sparker is shown in Fig. 1.

2.2. System setup

The system mainly consists of a low voltage rectifier and filter circuit, a H-bridge inverter, a high voltage transformer and rectifier, 8 energy storage capacitors, a discharging switch and multi-tips discharging electrodes.

Due to its simple circuit topology, good "short circuit" characteristic and constant-current characteristic, the series resonant circuit was adopted to charge the capacitors in the system [4, 5]. The H-bridge inverter was composed of two Intelligent Power Modules (IPM) (IPM100DVA120, Mitsubishi Corp.). A resonant capacitor of 0.33 μF and an inductance of 46 μH was connected in serial between the inverter and the transformer. The resonant frequency of the circuit was 40 kHz and the working frequency of the inverter was set at 20–25 kHz.

The toroidal Fe based microcrystalline magnetic core was used as the transformer's core, and the litz wire was used as the primary wind to reduce the skin effect. Figure 2 shows the photo of the high voltage high frequency transformer with a ratio of 1:10 and a stray inductance of 1 μH.

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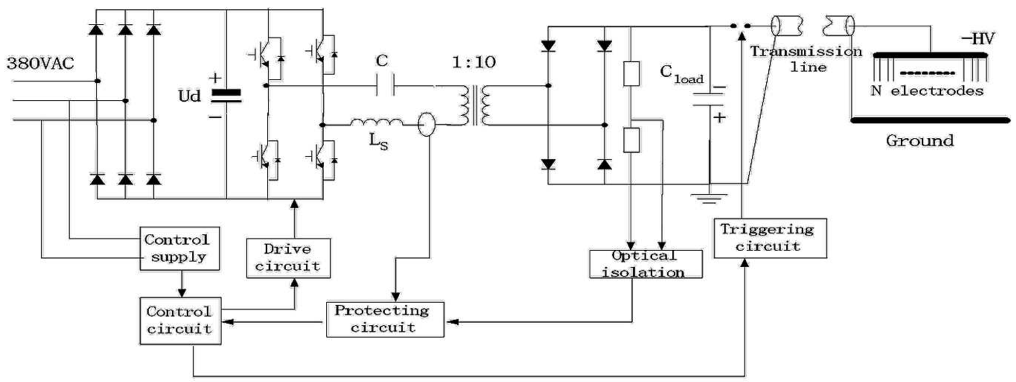

Fig. 1. Main circuit of the ocean sparker.

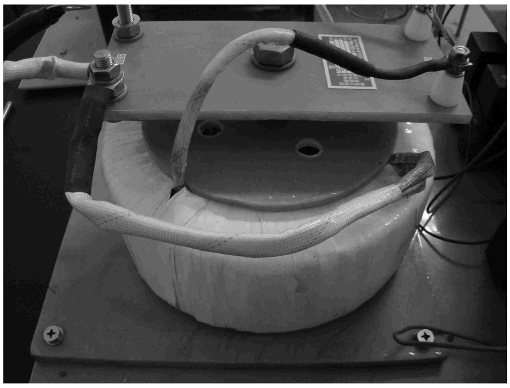

Fig. 2. High voltage transformer.

Fig. 3. High voltage thyristor.

A high voltage thyristor (KPc2600-65, TEG Corp.) was used as the discharging switch, with a rated voltage of 6.5 kV and a discharging current of 50 kA (less than 3 ms pulse duration), which is shown in Fig. 3.

8 capacitors (GKMJ5-200, Beijing Kejiaxin Research Institute of Capacitor) were adopted as the energy storage components which were connected in parallel, with a rated voltage of 5 kV, total stored energy of 20 kJ, and an expected lifetime of 2 millions shots. The discharging electrodes consisted of several hundreds tips of high voltage electrodes and one ground electrode, only the end of each tip contacted with the water.

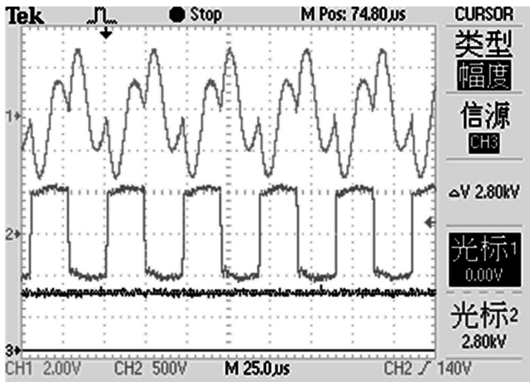

Fig. 4. Waveforms of the resonant current and the output voltage of the inverter.

3. Experimental results

3.1. Short circuit experiment

Short circuit test was done to check the component's capability (mainly the IPM and the high voltage transformer) in the charging supply. It lasted 3–5 min. The waveforms of the resonant current (Channel 1) and the output voltage of the inverter (Channel 2) are shown in Fig. 4. The current was measured by using a current sensor with a sensitivity of 20 A/V.

3.2. Load experiments

To check the performance of the system, the continuous experiments were conducted at repetitive rates of 12 shots/min under 4.5 kV, 1600 μF. After 4 hours, the temperature rises of the power components were less than 10°C and basically the system had reached a relative stable condition after that. The waveforms of the charging voltage (Channel 1) and envelope of the resonant current (Channel 2) are shown in Fig. 5.

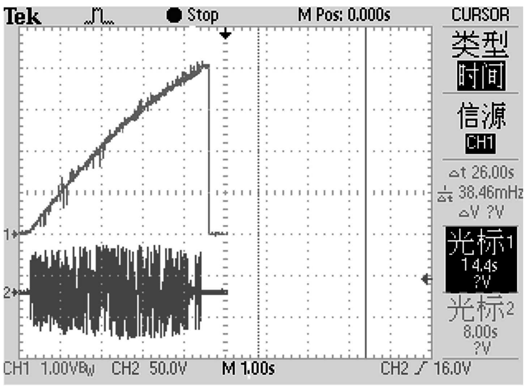

Fig. 5. Waveforms of the charging voltage and envelope of the resonant current.

The discharging voltage was recorded through a resistive divider with a ratio of 1:1000. It was indicated that the charging voltage rised approximately in linearity, and the charging current kept almost at a constant.

3.3. Multi-tip electrodes discharging experiments

Multi-tips electrodes experiments were carried out by using 200 tips, 500 tips and 1000 tips, respectively in the Lab. The voltage is 4 kV, the liquid conductivity is 14 ms/cm. The discharging current was measured through a 4.4 mΩ coaxial shunt and recorded by TDS220 oscilloscope (Tek. Corp.). The discharging currents are shown in Fig. 6. The discharging current is 8.2 kA (the FWHM is 0.6 ms) at 1000 tips while the current is 4.3 kA (the FWHM is 1.3 ms) at 200 tips. It can be deduced that the discharging current would reach 30–40 kA (the FWHM will be less than 0.2 ms) when discharging in the sea water with a conductivity of approximately 50 ms/cm and 2000 tips electrodes.

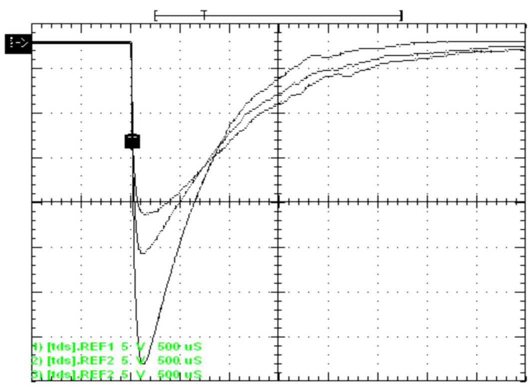

Fig. 6. Waveforms of the discharging current under different tips of electrodes.

4. Conclusions

A high energy sparker was developed for the high resolution ocean seismic survey, and some performance tests had been done in the laboratory. Good results had been achieved by using high frequency high voltage inverter technology and solid state switch technology. The sparker can be operated at repetition rates of 12 shots/min, and have more compact size, high reliability and stability.

Acknowledgments

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