Development of Pulsed Power System for 500kA Current Generation

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Abstract: The manufactured pulsed power system with 500kA current is described in this paper. The capacitor bank, control cabinet, dc charging unit, closing switch and dumping box, cable system etc. employed with the system components are described. Especially the development of the inverse pinch switch controlled by gas puffing enabled the generation of the very high voltage and current.

1. Introduction

The pulsed power is widely used for an aircraft, a motor car and generation of an atomic energy etc. It can be also applied to the fields of high-speed pulses of energy in different form, such as electric current and voltage, and shock waves in gases [1-2].

In case of Korea, the pulsed power equipment with several kV and kA were developed in the manufactory for electron beam, sterilization, electrical dust collector, and generation of ozone. But very few studies which aim at the high powered pulsed technologies with several kV, several hundred kA and several us are carried out.

In relation with this, the authors have conducted a series study on the pulsed power technology with high voltage and high current [3-11]. This paper is directed mainly at electrical engineers working for the practical application of high voltage and high current. The basic design technology for 500kA pulsed power system is presented in this paper. The ratings of capacitor bank, control cabinet, dc charging unit, switching device and

Power applying system etc. to be employed in this system is described. The design of a large charge transfer switch using inverse pinch switch enabled the generation of the very high voltage and current.

2. Pulsed Power System Configuration

2.1 Manufactured Pulsed Power System

The photograph of the pulsed power system is shown in Fig. 1. Its ratings are as follows:

- Max charging voltage : 11kV
- Total stored energy : 2,000kJ
- Max current : 500kA
- Pulse width of current : 0.8 ~ 1.2ms

The main components consist of the capacitor banks, DC charging unit, high current switch, and cable system etc. The aluminum box is shielded against the high voltage. The shielding wire of coaxial cable is also connected to aluminum box to suppress the strong electromagnetic wave. Capacitor bank with the metalized electrode of Aerovox Co., has high storage energy density (0.77kJ/kg), safe self-clearing against breakdown and long life of 413,000 shots at 9kV [8].

It has total capacitance of 32.2mF, rated at 9kV and total stored energy of 2,000kJ. The maximum power of DC charging unit is 75kVA. The capacitor charging time for 10kV will be limited to 2minutes. Coaxial cable for applying the power is designed to flow the current of several 500 kA and to have minimum weight for easier movement. The block diagram of manufactured system is shown in Fig. 2.

Fig. 1 Manufactured Pulsed power system

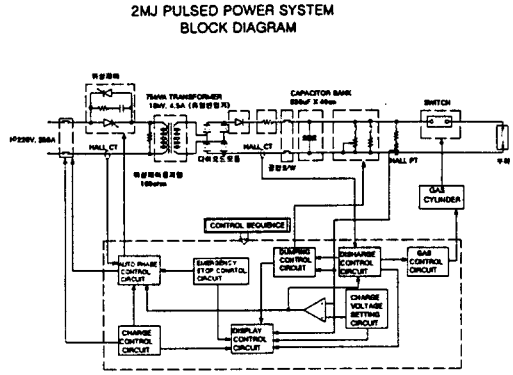


Fig. 2 Block Diagram of 2MJ Pulsed Power System

2.2 High Current Closing Switch

The representative closing switches for the high voltage & current are classified as table 1. The core of high-powered pulse system is switching technology for high voltage and high current [9]. As known from Paschen curve of the Fig.3, the less the product of pressure and gap distance is, the higher breakdown voltage becomes. Pseudospark phenomena, which were discovered in 1979, appear in the left area of minimum point of this curve [12,13].

Table 1 Example of closing switches

Division	Rating	Switching time	Repetition rate
Spark gap	~MV, ~MA	~10ns	~Hz
Thyratron	~50kV, ~100kA	~100ns	~kHz
Ignitron	~50kV, ~100kA	~ms	~100kHz

On the other hands, the inverse pinch switch is well used for closing the high voltage and high current. Spark gap switch shown in Fig. 4 is designed by Z-pinch principle. Therefore the electrode surface is damaged from the hot spot breakdown. To improve this problem, recently INPIStron switch is well used for the switch of pulsed power system. In principal, this switch shown in Fig. 5 is operated by vector F= vector J x vector B, so that current J can be flowed through all surface of the electrode. The performance of INPIStron switch is better than that of spark gap switch.

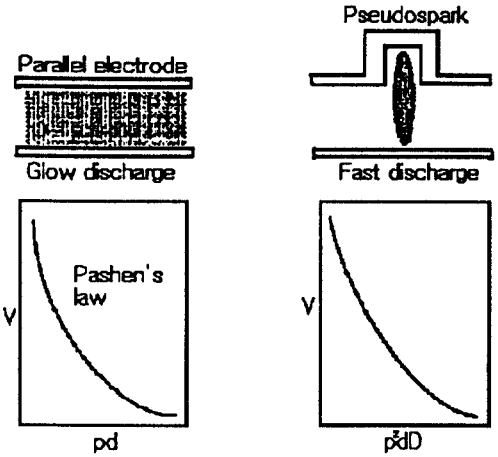


Fig.3 Breakdown characteristics of two different electrodes

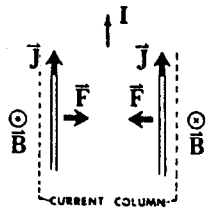


Fig. 4 Z-pinch

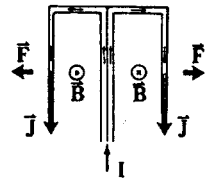
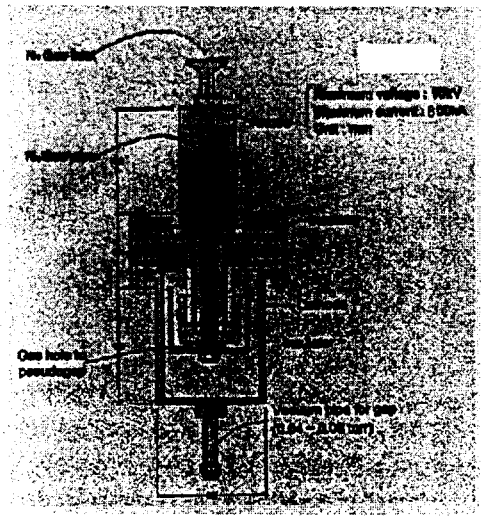
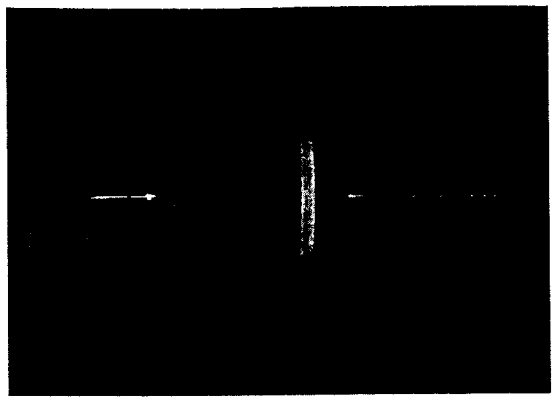


Fig. 5 Inverse-pinch

The inverse pinch switch, which discharges through the all surfaces of cathode electrode, has long life. The trigger of IPS switch happens by increasing the pressure of N2 gas supplied by the gap-puffing switch. According to the experimental results, the switch can be operated up to 5,000times by clearing the electrode surface. The electrode is made of tungsten for the good arc characteristics and the other switching parts are made of stainless steel. The anode and hollow are arranged symmetrically so they can be operated for reversal voltage. The inner construction and manufactured closing switch with 500kA are shown Fig.6 (a) and (b), respectively.



(a)Inner construction of IPS



(b) Photograph of manufactured IPS

Fig.6 Manufactured inverse pinch switch (IPS) for 500kA-pulse current

2.3 Dumping Switch

Dumping switch is established for eliminating the residual charge of capacitor bank after closing of high current switch. The numbers of resistors in dumping box are 30 with 2.7 kΩ resistance and 2kW power. The total resistance and electric power are 90 ohm and 81 kW, respectively. The eliminating time of the residual charge is about 10 second. The working circuits and photograph for dumping box are shown in Fig. 7 and Fig. 8. Also the relation between the dumping resistance and time is shown in Table 2.

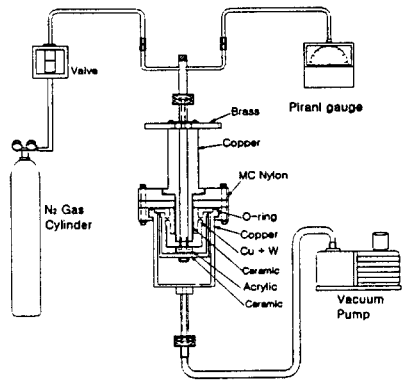


Fig. 7 Dumping circuit

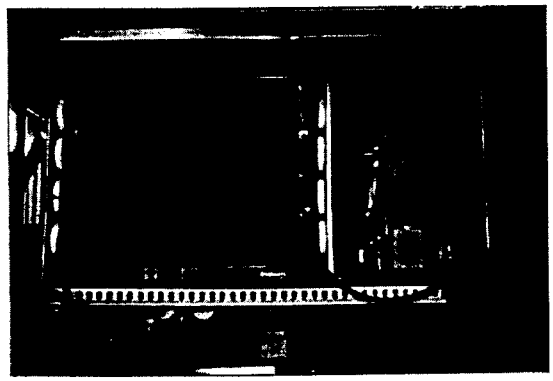


Fig. 8 Dump switch

Table 2 Resistance variance dependency on time

Resistance [ohm]	Time [sec]
1200	0.5
1000	1
850	1.5
700	2
600	2.5
500	3
400	3.5
350	4
250	4.5
200	5
150	6
100	7
50	8.5
0	9.5

3. Application Fields of the Pulsed Power

The pulsed power is widely used for an aircraft, a motor car and generation of an atomic energy etc. It can be also applied to the fields of high-speed pulses of energy in different form, such as electric current and voltage, and shock waves in gases. The followings give the representative examples in the use of pulse power system.

- Rock fragmentation and destruction of an out-worn building
- Remote sealing operations for nuclear fuel container of waste materials
- Power supply for electromagnetic press
- Production of parts for an aircraft, a motor car, breaker etc.
- Synchrotron radiation, E-beam welding machine, fusion
- Generation of an atomic energy, Plasma, Laser, Microwave,
-Generation of beam of electrons, x-rays, gamma rays, sound and shock waves in gases and liquids.

Fig 9 shows actual application for concrete with 1m diameter. As shown in the figure, our developed pulse power system gave very good performance for the commercial application.

Fig.9 Concrete fragmentation test by using the 500kA pulsed power system

4. Conclusions

The pulsed power system with 500 kA was manufactured through the experiments and computer simulation. A new inverse pinch switch triggered by N2 gas puffing gives good performance for breaking a large current up to 500kA. Our switch can be operated up to 5,000times operations. The dumping box with 90 ohm can eliminate the residual charge within about 10 second. The capacitors (830uF x 40ea) are arranged so that the inductance of the system can be minimized.

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