SOLID STATE SWITCH BASED PULSERS FOR THE INJECTION SYSTEM OF THE COLLIDER VEPP-2000

B.I. Grishanov, F.V. Podgorny, A.S. Kasaev
The Budker Institute of Nuclear Physics SB RAS
630090, Novosibirsk, Lavrentieva av., 11 RUSSIA
E-mail: grishanov@inp.nsk.su

We describe high voltage pulsers for supplying the kickers of the collider VEPP-2000 injection system. The high voltage pulse is formed as a result of a sharp break of a high current, accumulated previously in storage elements, by means of a SOS-diode The generator scheme is described too.

PACS: 29.20.Dh

1. TECHNICAL SPECIFICATION

Generators are designed for a kicker system feeding of injection electrons and positrons in the collider VEPP-2000 in the Budker Institute of Nuclear Physics, SB RAS.

The injection system kickers are elements of the accelerator itself and are placed together with it in the radiation-protected hall. Structurally kickers are executed as asymmetrical strip lines and operate in the matched mode on the counter traveling wave (in relation to a particle movement direction). The feeding pulse is supplied to one end of a plate of the kicker; the matched load is connected to another end. Kicker's plates having the length of about 1.5 m are placed directly in the vacuum chamber of the storage ring VEPP-2000. The plates are fastened on the ends of the feedthroughs [1].

The injection system includes two kickers, and both of them are used alternatively for injection and storage of electrons and positrons. As the kickers operate in the counter traveling wave mode, at changeover from the electron storage mode to the positron storage mode and back it is necessary to change both the polarity of pulses, and the wave direction. Such switching is carried out operatively from the complex main control panel by electromechanical devices. The kickers have a 50-Ohm wave resistance; designed pulse amplitude on kicker inputs is 50 kV.

Pulser's specifications

Output pulse amplitude	30-50 kV
Rise/fall time	≤ 30 ns
Flat-top duration	≥ 15 ns
Flap-top nonuniformity	< 10 %
Pulse amplitude instability	< 0.5 %
Jitter	< 1 ns
Load	50 Ohm
Repetition rate	≤ 2 Hz

2. PULSE FORMING TECHNIQUES

There are some variants of the task solution. Their basic difference from each other consists in a mode of an energy accumulation. One of them is a switching of a preliminary charged forming line to the load. Thyratrons or spark-gap switches are used in this scheme as the switch usually. There is a wide experience in development of such generators in the Institute [2].

Other variant consists of energy accumulation in the inductance of the forming line (or in the lumped inductance) and using of a current breaker. Thus the broken-off current is thrown in the load. The description of this process is given below.

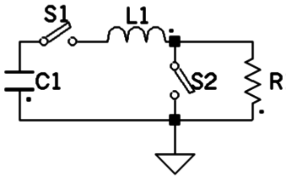

Fig.1Circuit with current breaker

The energy from a preliminary charged capacitor C1 is swapped in the inductance L1 through switches S1 and S2. The switch S2 is turn-off at the maximal current moment. As a result the pulse with an exponential transient time constant L1/R1 appears on the load. It is possible to use a so-called SOS-diode as the switch S2. The real circuit with the SOS-diode is a little more complex then above-mentioned one and is described below.

The theory of the phenomenon, which has named SOS-effect is described in detail in papers [3,4]. These works were executed in the Institute of Electrophysics, Ural Branch the Russian Academy of Science. Besides this institute is the developer of the SOS-diodes. The SOS-diodes allow operate over a wide range both of the current, and of the voltage. Initially the SOS-diodes have been optimized to obtain the sharp edges and to have an opportunity of operating in a frequency mode. For our experiments S.N.Rukin has kindly given us two devices, which differed by the diodes junction area.

One of variants of the scheme, allowing one to provide an operating mode of the SOS-diode, is presented below.

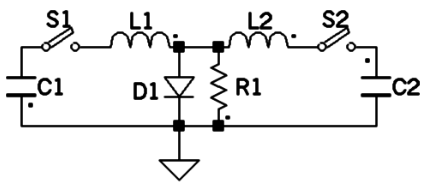

Fig.2. Two-circuit scheme

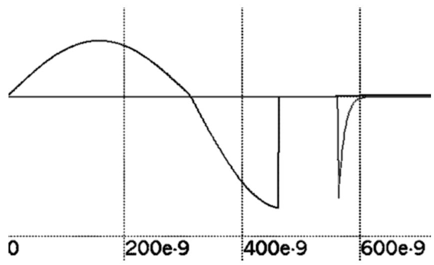

Fig.3. The SOS-diode current and the load pulse

Capacitors C1 and C2 are preliminary charged to an opposite polarity voltage. The switch S1 is turned-on at first. The sine wave current in C1-L1-D1 circuit is formed. The first half wave of this current runs through the SOS-diode in a forward direction. When the SOS-diode current is crossing a zero-level, the SOS-diode remains open during a short time, therefore the inverse current half wave runs through the SOS-diode also. When the SOS-diode current is crossing a zero-level the switch S2 starts the similar process in the circuit C2-L2-D1. From this time the diode currents of both circuits run in the same direction and are summarized. On this half wave the current through the diode is the opposite.

Parameters of the scheme and charge voltage set a mode of appearance of a SOS-effect. During the moment when the current value is close to a maximum, in the diode there is a sharp breakage of the current, and on the load the pulse is formed. The current can break not only at the moment of a maximum, but also at other moments. In order to produce conditions for appearance of the process named as a SOS-effect, it is necessary to create the required density of the direct excitation current and the inverse excitation current during certain time.

In such a scheme by selection of the parameters of circuits' elements it is turns out that the break-off current exceeds sufficiently the direct excitation current. Thus it is possible to obtain on the load pulse amplitude greatly more than the charge voltage. So, to get the high voltage pulses of the set amplitude it is possible to do it at a lower charge voltage. Besides, the switches S1and S2 can be not high-voltage ones.

The SOS-diode is characterized by several parameters. They are: direct and inverse excitation currents, direct and inverse excitation duration, the maximum broken off inverse current and the maximum voltage, which can hold the diode after current breakage. The inverse excitation duration influences on the current breakage speed and on the formed pulse rise time consequently. Direct excitation duration can be changed in more wide limits and is restricted above by electron-hole plasma recombination effects in the diode. In detail it is described in [4].

From very beginning we have a single sample of the SOS-diode for our experiments. This diode allowed one to break-off the inverse current of up to 4 kA in a pulse magnitude. The direct excitation duration could be changed within the limits of 200-500 nanoseconds, and inverse excitation duration within the limits of 80-150 nanoseconds. In accordance with developer’s recommendations, the maximum speed of the current breakage could be reached at the inverse excitation duration of about 100 ns. The formed pulse rise time could reach a few nanoseconds.

To obtain a rectangular pulse, it is possible to use two ways. The first one consists in using the energy storage in the pulse forming line inductance. The second one consists in using the lumped inductance and application of correction circuits. The last approach to obtaining a quasi-rectangular pulse was written in [5].

3. EXPERIMENTS

3.1. 4-KA DIODE

Our first experiments with 4-kA-diode have shown, that we "see" the SOS-effect in the scheme submitted below. This scheme differs from the scheme in fig.2, we call its scheme with consecutive excitation. Oscillograms of the diode D1 current and a pulse on the load R1 are presented in fig.5.

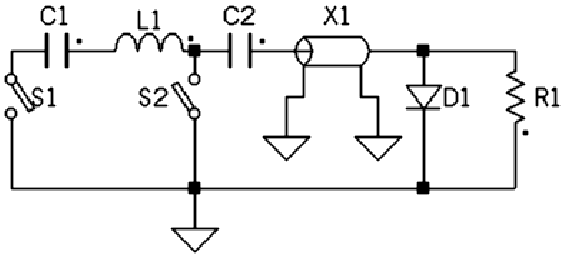

Fig.4. Two-circuit scheme with pulse forming line

Fig.5. The load pulse oscillograms

The dual-circuit scheme has two switches. As a switch S1 we use the Russian hydrogen thyratron TGI1-1000/25, and as a S2 – the magnetic switch. The permalloy core 50NP having the size 70x40x15 was used. The operating cycle looks as follows. Capacitor C1 is charged up to an operating voltage, then the thyratron S1 is turned on. The current is running on the contour C1-L1-L2-C2-D1 and charges capacitor C2 up to the voltage proportional to the initial capacitor C1 voltage. The switch S2 core is saturated to this moment, the current starts to run on the circuit S2-L2-C2-D1. The second circuit parameters and the initial capacitor C1 voltage define this current amplitude. The diode current breaks at the moment close to its maximum. As a result the pulse on the load is formed.

We use the KVI-3 type capacitor for C1 and C2. Values of scheme elements are the following: the capacity C1=6,6 nF, the capacity C2=5,5 nF, inductance L1=5,5 μH. Inductance L2 is the inductance of the 3 meters length piece of RK50-9 type cable, L2=0.75 μ H. The SOS-diode is placed in a coffee-bank. The magnetic switch is seen at the left. Degaussing circuit is placed in the cardboard cylinder.

As the magnetic switch does not allow adjusting the charge voltage level within a wide range, the magnetic switch S2 has been replaced by the thyratron TGI1-1000/25 with the grounded anode. Feeding of the cathode heater and the driver pulse is supplied via a special decoupling choke. The further experiments with this scheme and this SOS-diode showed that the pulse shape on load varies with the increase in the excitation level very strong. The pulse shape becomes nonrectangular. It means, that the switching characteristic of the SOS-diode strongly changes with charge voltage changing.

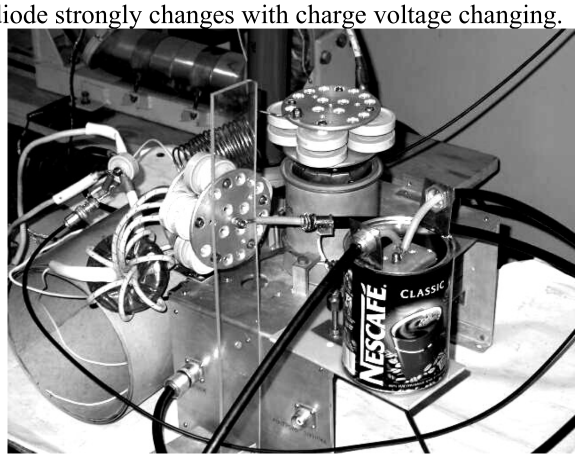

Fig.6. Test stand

To reveal correlations between the scheme parameters and the pulse shape a series of experiences using the Latin square method has been carried out. A measure of significance of each of factors was determined and, that is more important, the required pulse shape of the necessary amplitude was received at the certain set of parameters.

Being based on the results obtained, we came to a conclusion, that it is necessary to have a lower current density in the diode for our pulse specifications. As a result of discussion of these experiments with S.N.Rukin, it became clear, that it is meaningful to repeat these experiments with the diode of the essentially greater junction area, i.e. to proceed in a mode with a lower excitation current density. Such diode has been given to us.

3.2. LOW DENSITY CURRENT DIODE

Having repeated the series of experiments with the new diode, it has been found out, that the parameters of this diode practically do not influence the pulse shape in a wide range of modes. It confirmed the assumption made before. The pulse shape depends only on elements parameters of the scheme.

The inverse excitation circuit inductance consists of the 1.2 meters length piece of RK50-9 type cable. As a result we formed the pulse on the 50-Ohm load, corresponding to the technical specification. The pulse amplitude is over 50 kV. The oscillograms are shown in fig.7. The charge voltage is 17 kV, a measure divider coefficient is equal to 13000.

Close results were obtained with the lumped inductance as the energy storage element in the inverse excitation circuit. In these experiments the pulse amplitude reached 70 kV. The pulse shape was not so rectangular, but it may be improved by means of correction circuits.

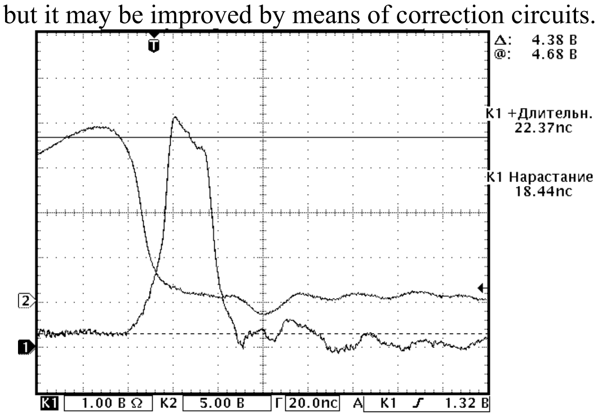

Fig.7. The load pulse oscillograms

4. RESULTS

The experimental results obtained are the base for the design of a working variant of the kicker feeding pulsers for the collider VEPP-2000.

CONCLUSIONS

Authors thank to S.N.Rukin for the given samples of diodes and useful discussions and consultations

REFERENCES

1. B.I. Grishanov, F.V. Podgorny. Injection in the storage ring VEPP-2000. *HEACC-2001*.
2. M.G. Bakharev, B.I.Grishanov, F.V. Podgorny. High-voltage short pulse generator. *PAC-2001*.
3. S.K.Lyubutin, G.A.Mesyats, S.N.Rukin, B.G.Slovikovskii, A.M.Turov New solid state opening switches for repetitive pulsed power technology // *Proc.: XI Int. Conf. on High Power Particle Beams*., Prague, Czech Republic. 1996, v.1, p.135-138.
4. S.A.Darznek, G.A.Mesyats, S.N.Rukin, S.N. Tsiranov. Theoretical model of the SOS effect // *Proc.: XI Int. Conf. on High Power Particle Beams*. Prague, Czech Republic. 1996, v.2, p.1241-1244.
5. S.K.Lyubutin, G.A.Mesyats, S.N.Rukin, B.G.Slovikovskii, S.N.Tsiranov Generator of quasi-rectangular pulses on the low ohmic load with an semiconductor current interrupter // *PTE*. 2000, No.1, p.74-81.

ИМПУЛЬСНЫЕ ГЕНЕРАТОРЫ НА ОСНОВЕ ТВЕРДОТЕЛЬНЫХ КОММУТАТОРОВ ДЛЯ СИСТЕМЫ ИНЖЕКЦИИ КОЛЛАЙДЕРА ВЭПП-2000

Б.И. Гришанов, Ф.В. Подгорный, А.С. Касаев

Описаны генераторы высоковольтных импульсов для питания кикеров системы инжекции коллайдера ВЭПП-2000 БИЯФ СО РАН. Формирование импульсов происходит в результате резкого обрыва тока в ин-

дуктивном накопителе при помощи сборки из полупроводниковых SOS-диодов, включенной параллельно нагрузке. Приведена схема генератора.

ІМПУЛЬСНІ ГЕНЕРАТОРИ НА ОСНОВІ ТВЕРДОТІЛЬНИХ КОМУТАТОРІВ ДЛЯ СИСТЕМИ ІНЖЕКЦІЇ КОЛЛАЙДЕРА ВЕПП-2000

Б.І. Гришанов, Ф.В. Підгорський, А.С. Касаев

Описано генератори високовольтних імпульсів для живлення кикеров системи інжекції коллайдера ВЕПП-2000 БИЯФ З РАНЕЙ. Формування імпульсів відбувається в результаті різкого обриву струму в індуктивному накопичувачі за допомогою зборки з напівпровідникових SOS-діодів, включеної паралельно навантаженню. Приведено схему генератора.