SOS-DIODE BASED PULSER FOR THE INJECTION SYSTEM OF THE COLLIDER VEPP-2000

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Abstract

We describe a high voltage pulser for supplying of 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 SOS-diode. Pulse forming lines or inductances could be used as the storage elements. The generators form the quasi-rectangular pulses on the 50-Ohm load. We investigated the SOS-diodes characteristics in wide regime region. The generator scheme is described also.

1 TECHNICAL SPECIFICATION

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

The injection system kickers are elements of the accelerator itself and are placed together with it in a radiation-protected hall. Structurally kickers are executed as asymmetrical strip lines and operate in the matched mode on a counter traveling wave (in relation to a particles movement direction). The feeding pulse is supply to one end of a plate of the kicker; the matched load is connected to another end. Kicker's plates have length of about 1.5 m, are placed directly in the vacuum chamber of the storage ring VEPP-2000. The plates fasten on the ends of feed-throughs [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 a electrons storage mode to a positrons storage mode and back it is necessary to change both polarity of the pulses, and the wave direction. Such switching is carried out operatively from a 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 decision. 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 Institute [2].

Other variant consists of energy accumulation in 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 submitted below.

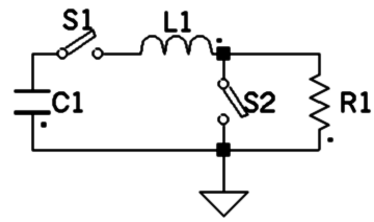

Fig. 1. Scheme with current breaker.

The energy from a preliminary charged capacitor C1 is swapped in an 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 scheme with the SOS-diode is a little bit more complex of mentioned above and is described below.

The theory of the phenomenon, which has named SOS-effect is described in detail in papers [3, 4]. These jobs was executed in 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. The SOS-diodes have initially been optimised for reception of sharp edges and an opportunity of operate in a frequency mode. For our experiments S.N.Rukin has kindly given to us two devices, which differed by the diodes junction area.

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

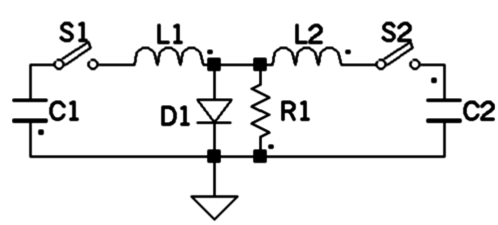

Fig. 2. Two-circuit scheme.

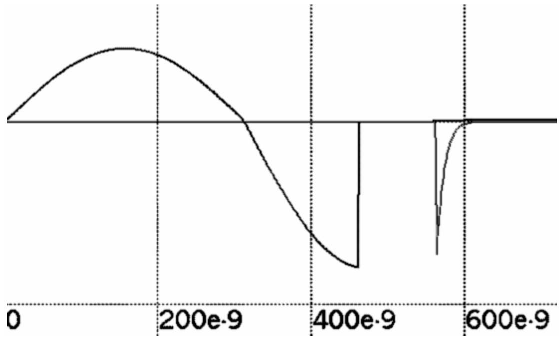

Fig. 3. The SOS-diode current and the load pulse.

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 circuit C2-L2-D1. From this time the diode currents of both circuits runs 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 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 other moments. In order to produce conditions for appearance of the process named 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 scheme by selection of the circuits' elements parameters it is turns out to break-off the current that exceeds sufficiently straight 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 smaller charge voltage. The switches S1и S2 can be not high-voltage also.

The SOS-diode are characterized by several parameters. They are: direct and inverse excitation currents, direct and inverse excitation duration, the maximal broken off inverse current and the maximal 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 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 recommendations, the maximal speed of the current breakage could be reached at the inverse excitation duration about of 100 ns. The formed pulse rise time could be reached a few nanoseconds.

To receive a rectangular pulse, it is possible to use two ways. The first one is consists in using of energy storage in the pulse forming line inductance. The second one - in using of 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 on fig. 2, we call its scheme with consecutive excitation. Oscillograms of the diode D1 current and a pulse on the load R1 are presented on fig. 5.

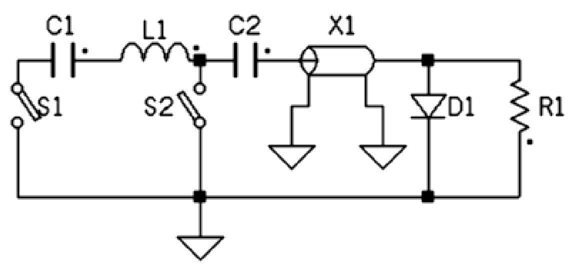

Fig. 4. Two-circuit scheme with pulse forming line.

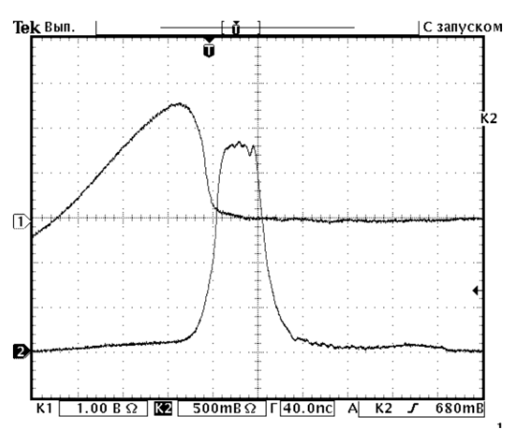

Fig. 5. The load pulse oscillograms.

The dual-circuit scheme has two switches. As the switch S1 we use a Russian hydrogen thyratron TGI1-1000/25, and as the S2 – a magnetic switch. It was used permalloy core 50NP by the size 70x40x15. The operating cycle looks as follows. Capacitor C1 is charged up to a operating voltage, then the thyratron S1 is turned on. The current running on 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 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 the result the pulse on the load is formed.

We use the KVI-3 type capacitor for C1 and C2. Values of scheme elements the following: the capacity C1=6,6 nF, the capacity C2=5,5 nF, inductance L1=5,5 uH. Inductance L2 is the inductance of the 3 meters length piece RK50-9 type cable, L2=0.75 uH. 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.

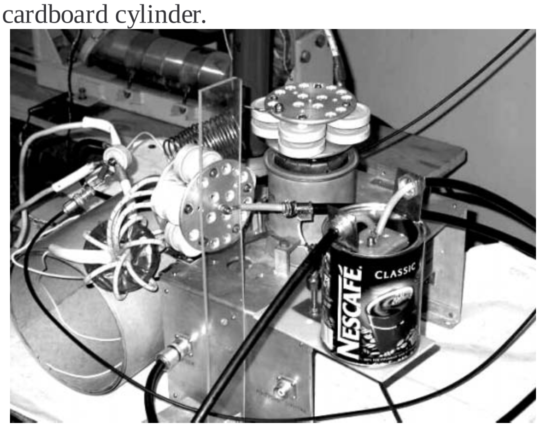

Fig. 6. Test stand.

As the magnetic switch does not allow adjusting the charge voltage level within a wide range, magnetic switch S2 has been replaced by thyratron TGI1-1000/25 with the grounded anode. A cathode heater feeding and a driver's pulse supply through a special decoupling choke. The further experiments with this scheme and this SOS-diode have shown, that the pulse shape on load varies at increase in an excitation level very strong. The pulse shape becomes nonrectangular. It means, that the switching characteristic of the SOS-diode strongly changes at change of the charge voltage.

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

Being based on the received results, we came to a conclusion, that it is necessary to have smaller current density in the diode for our pulse specifications. As a result of these experiments discussion 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 smaller excitation current density. Such diode has been given to us.

3.2 Low density current diode

Having repeated the experiences series 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 RK50-9 type cable. As the result we has formed the pulse on the 50-Ohm load, which correspond to technical specification. The pulse amplitude is over 50 kV. The oscillograms is shown on fig. 7. The charge voltage was 17 kV, a measure divider coefficient is equal to 13000.

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

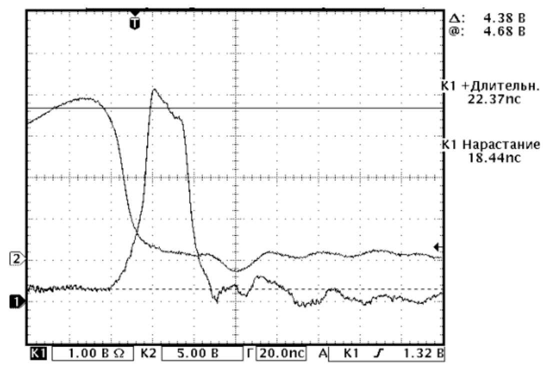

Fig. 7. The load pulse oscillograms.

4 RESULTS

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

5 ACKNOWLEDGEMENTS

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

6 REFERENCES

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