High Voltage Nanosecond Generators For SIBERIA-2

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A single tern injection scheme with two kickers and one septum is used for injection into booster (SIBERIA-1 storage ring) and into main ring (SIBERIA-2) One kicker and one septum are used for extraction from SIBERIA-1 into transport line to main ring. The fast kickers generate electromagnetic pulses with rise and down time of 3 ns and flat top of 15 ns duration. The high voltage pulse generators with double coaxial forming lines and three electrode nitrogen filled spark gaps are intended for linac electron gun and fast kickers supply. The output pulses are up to 60 kV in amplitude. A root-mean-square time spread of the moments when the signal comes to the kicker plates is 0.7-0.8 ns. The experimental results of operation of the generators obtained while commissioning SIBERIA-2 are presented.

I. INTRODUCTION

The injection part of the SIBERIA-2 consists of 80 MeV electron linear accelerator, a 450 MeV booster storage ring SIBERIA-1 and two electron transfer lines - TL-1 and TL-2[1]. The single turn injection scheme uses fast kickers for injection into booster and from booster to main ring [2]. In November - December of 1992 the linac and SIBERIA-1 were commissioned and now the work is continued with the 450 MeV electron in SIBERIA-1. SIBERIA-1 operates in single bunch mode and the stored current is supposed to be 100 mA. The 450 MeV beam has the energy spread $\sigma_E/E = 3.9 \times 10^{-4}$, the bunch length is $\sigma_s = 30$ cm and its horizontal emittance is $\varepsilon = 8.6 \times 10^{-5}$ cm-rad. In July 1994 the 450 MeV electron bunch was extracted from SIBERIA-1 and conducted through transfer line TL-2. In December 1994 SIBERIA-2 were commissioned and we have got first turn of electron beam. February 1995 - ther were about one thousand turns. And on April 17 there was first beam in storage ring with life time about 2 hours.

The injection scheme requires pulses for kickers with 7 -- 60 kV amplitude (Table 1). For efficiency of injection a time stability about 1--2 ns of the moment when the pulse comes to the kicker is needed .

II. HIGH VOLTAGE NANOSECOND GENERATORS

The kickers are fed by the bipolar high voltage nanosecond generators and operate in a traveling wave mode. Figure 1 presents a scheme of the bipolar generator. The generator operates on the basis of the fast discharge of double forming lines which are connected to the kicker plates by SF_6 filled coaxial cables. The discharge is realized by gaseous spark gap (the so-called 3-electrode discharger). The discharge is initiated by a thyratron connected to the central electrodes of the dischargers. The discharge moment is tuned by varying the pressure (5 - 17 atmospheres) of nitrogen inside discharger. The pulse duration is equal to double propagation time of electromagnetic wave traveling along the forming line.

Table 1
Parameters of the kickers and the generators

Device	Forming line voltage, kV	Gap width, mm	Kicker plates voltage, kV	Rms time spread, ns	Notes
Linac electron gun	53	0.6 1.2	-40	0.6 - 1.3	Operates since June 2, 1992, 6.5 million pulses
SIBERIA-1 kicker	37	0.4 0.8	±6	0.6 - 1.5	Attenuation 6×
SIBERIA-1 prekicker	31	0.31 0.62	+4.6	0.7 - 1.2	Attenuation 6×, monopolar
SIBERIA-1 extraction kicker	38	0.42 0.85	±31	0.6 0.8	
SIBERIA-2 prekicker	52	0.6 1.2	±45	??	Commissioning and first testing
SIBERIA-2 kicker	52	0.6 1.2	±45	0.5 - 0.9	

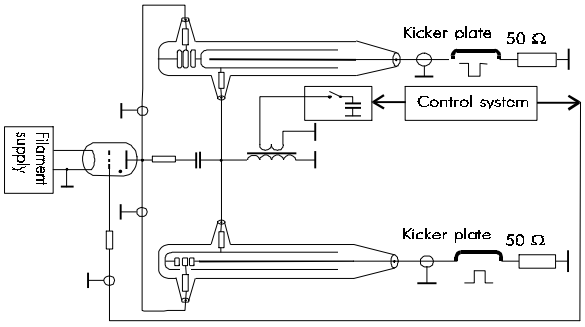

Figure 1: The simplified scheme of high voltage generator.

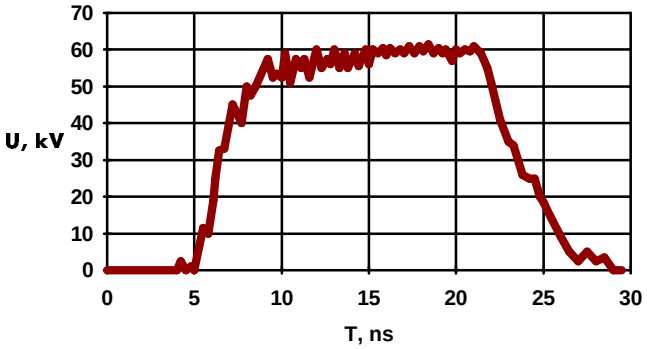

Figure 2: Oscillogram of output impulse 60 kV in amplitude.

In the case of high amplitude nanosecond pulse, the double forming line has a following advantages in comparison with the single forming line: it enables one to reduce twice the charging voltage and to simplify the scheme of the generator, because this makes it possible to give up invertors for producing pulses of opposite polarities. Polarity of output pulse depends on how gaps are connected up between forming lines.

The dischager's electrodes are made of duralumin, because this material provides appropriate training time of electrodes.

A pulsed hydrogen thyratron is used to start up spark gaps. All elements of generator, transport lines and kickers have wave impedance 50 Ohm. A pulsed transformer with epoxy isolation and transformation coefficient about 100 charges forming lines. Start up circuit is charged to one third of charging voltage due to capacity divider.

A low voltage (800 V) pulsed generator feeds a primary winding of the transformer. SF_6 gas fills cables and cable lead-ins at a pressure 5 atmospheres to increase electrical strength.

Resistance's and capacity's dividers (not shown in Figure 1) allow us measure voltage and monitor shape of pulses.

A control system uses electronics in CAMAC standard: microcomputer, ADC unit, etc. For time measurements we use time-digit converter unit with 0.6 ns per bit resolution. Software can measure average time delay, root-mean-square spread and changes of these values during long time.

III. EXPERIMENTAL RESULTS

An oscillogram of output positive pulse with amplitude 60 kV is shown in Figure 2. The spark gaps provide enough fast rise and down time of pulse. The rise time is about 3 ns, pulse's flat top is 13 ns, and down time is 5 ns.

A negative impulse has roughly the same characteristics. We have got 0.7--0.8 ns root-mean-square time spread of the moment when the pulse comes to kicker plates after careful installation, tuning and 100,000 pulses training of the spark gaps. This is right when charging voltage is between 20 and 60 kV and spark gap width is in range 0.4 - 1.2 mm. In the case of lower voltages (for kicker and prekicker of SIBERIA-1) we should use 50 Ohm attenuators at the entrance of the forming lines. The results of examining of time stability of the generator during working shift are shown in figures 3, 4.

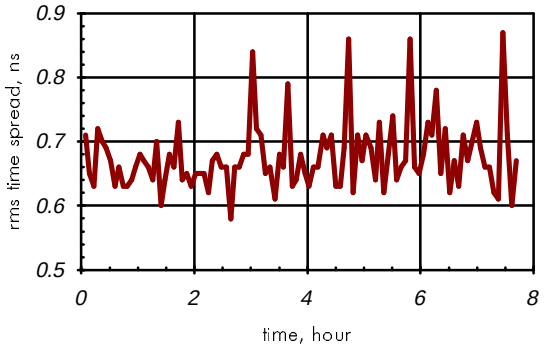

Figure 3: Rms time spread of the moment when pulse comes to kicker plates during working shift.

A stable thyratron operation needs stabilization of filament voltage not worse then 0.05% (decrease of 1% gives about 50 ns increase of output time).

With long operation time, erosion of electrodes occurs that leads to increase of gaps. First it results in increase time of gaps and then leads to decrease of operation's stability of generator. Figure 5 shows increasing of time delay of spark gaps due to wear and tear of electrodes.

Figure 6 shows the range of charging voltage with stable operation of extraction kicker generator. We use pressure of nitrogen in dischargers to obtain suitable time spread (rms not more than 1.5 ns) and number of electrical breakdowns in spark gaps (not more than 1%).

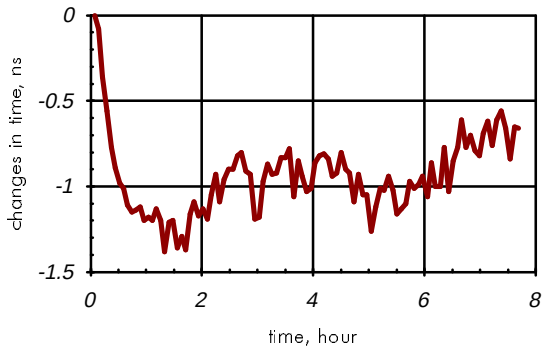

Figure 4: Changes of time when the pulse comes to kicker plates during working shift.

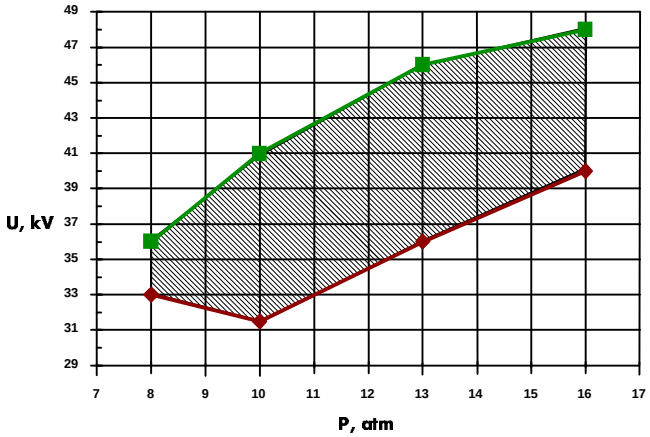

Figure 6: The range of the stable operation of the generator for extraction kicker of SIBERIA-1.

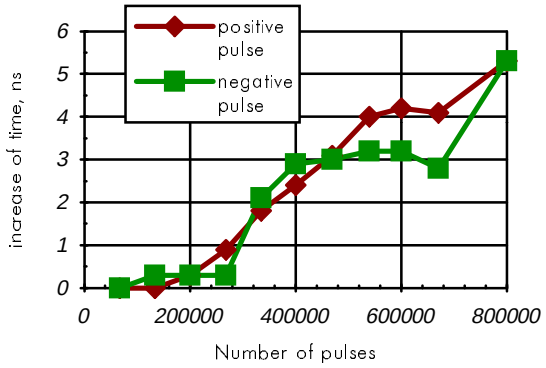

Figure 5: Time delay's increasing of spark gaps due to wear and tear of electrodes.

The generators have sufficient resources. The generator for linac electron gun operates during 250 working shifts (about 6.5 million pulses) without any repair.

The obtained results let us make a conclusion that these high voltage generators suit for reliable pulsed power supply of injection system for SIBERIA-2 storage ring.

For more detailed information on the subject, please contact us by the addresses given under the headline, or use e-mail: kadnikov@ksrs.msk.su.

IV. REFERENCES

[1] V.V.Anashin et al, Nucl. Instr. and Meth. A282 (1989) 369 - 374

[2] G.Erg et al. "Injection system for the SIBERIA-2 storage ring", Proceedings of the 1993 IEEE Particle Accelerator Conference, Washington, 1384 - 1386.