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HIGH VOLTAGE GENERATORS UPGRADE OF SIBERIA-2 INJECTION SYSTEM

S. Tomin#, A. Belkov, V. Korchuganov, K. Kuznetsov, I. Kuzmin,
NRC Kurchatov Institute, Moscow, Russia

Abstract

The injection system is one of the important systems of the accelerator facility which determines efficiency and reliability of the light source operation. Spark gap switches, which were used in HV pulse generators, are the critical components requiring high-maintenance. SGS has a series of limitations as high jitter and high pressure atmosphere of nitrogen. The new injection system is used Pseudo-Spark Switches generators of half-sine pulses.

In the article some technical aspects of the HV injection system are considered. Also results of generators operation are shown.

INTRODUCTION

Old injection system of Siberia-2 consisted of two kickers ("kicker" and "prekicker") and two bipolar generators. Each of the generators contained two spark gap switches and two double forming lines for each plate of a kicker [1,2]. In the injection moment electron beam was deflected in the electromagnetic travelling wave. This system was considered as reliable. However its servicing was labour-consuming, since the generators operated at 40-55 kV. In order to prevent breakdown of transit cables SF_6 gas filling was needed. Moreover adjustment of spark gap switches required continuous monitoring of nitrogen pressure in output chains. Thus a combination of HV electro-technical equipment of the generators with the high pressure gas equipment required much time for tuning that complicating the exploitation. Besides that the generators had to be always trained in order to hold jitter in right range, which reduced a life time of spark gap switches. On the contrary new generators are simple in servicing and could be quickly tuned. They operate in "current deflection" mode. Injection in Siberia-2 needs a current range 0.7-1.3 kA corresponding to charge voltage of 7-25 kV depending on pulse duration. In that case no SF_6 gas filling is required.

THE OLD GENERATORS OVERVIEW

The kickers were fed by the bipolar high voltage nanosecond generators and operated in a traveling wave mode. Figure 1 presents a scheme of the bipolar generator. The generator operated on the basis of the fast discharge of double forming lines which were connected to the kicker plates. The discharge was realized by gaseous spark gap (the so-called 3-electrode spark gaps). The discharge was initiated by a thyratron TGI-1k/25 connected to the central electrodes of the spark gap. The discharge moment of both SGS was tuned by varying the pressure (5 - 17 atmospheres) of nitrogen inside the switch. The pulse duration was equal to double propagation time of electromagnetic wave traveling along the forming line.

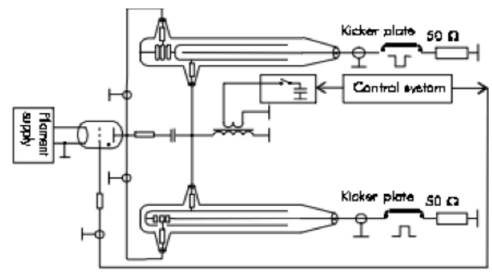

Figure 1: Simplified scheme of high voltage generator [1].

All elements of generator, transport lines and kickers had wave impedance 50 Ohm. A pulsed transformer with transformation coefficient about 100 charged forming lines. A low voltage (800 V) pulsed generator fed a primary winding of the transformer. The forming lines were charged for about 50 kV (for "kicker"). Start up circuit was charged to one third of charging voltage due to capacity divider. SF_6 gas filled cables and cable lead-ins at a pressure 5 atmospheres to increase electrical strength. Oscillogram of output pulse on kicker plate on Fig. 2 is shown.

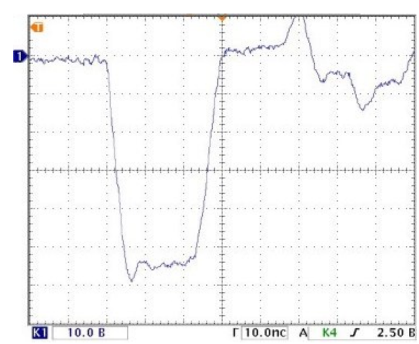

Figure 2: Oscillogram of negative output pulse on kicker plate.

It should be noted that for injection of an electron bunch on the kicker plates it was necessary to have about 32 kV on kicker and about 21 kV on pre kicker. Thus about 7 kV of 50 kV was lost on the discharger, the remaining on the long transit lines (length of lines were about 100 meters).

#tomin.sergey@gmail.com

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THE NEW GENERATORS OVERVIEW

New generators operate in the current deflection mode. In other words the particle beams are deflected only by magnetic field instead of electromagnetic field of travelling wave in the old generators. With simulation experiments at Siberia-2 there was shown the current of 0.7-1.3 kA along the kicker plates is needed for injection of an electron bunch. The mentioned current range corresponds to 21-32 kV of the voltage on the kicker plates while operating in traveling wave mode. One of the simplest ways to achieve such pulse is RLC circuit (resonant circuit). In that case transit lines and kickers represent some inductivity. To decrease transit lines inductivity the generator should be placed in the proximity from kicker.

To check the efficiency of the described scheme, a prototype of a new generator was created.

Prototype

The prototype included a HV pulse power supply, charge capacity of 7500 pF, pseudo-spark switch - thyratron TPI1- 10к/50 [3] and its driver. The simplified scheme of prototype is shown in Fig. 3.

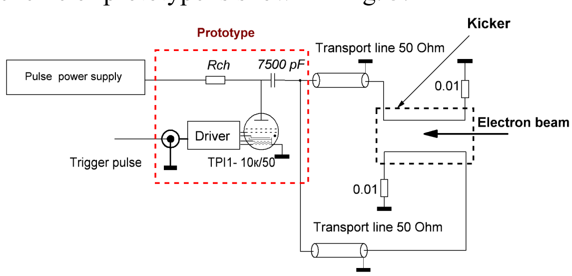

Figure 3: The simplified scheme of prototype.

Transport lines have the wave impedances equal to 50 Ohm and the lengths 1.25 meters, Fig. 3.

Tests were performed during injection of electron beam into storage ring Siberia-2. Max. injection efficiency was achieved at 23 kV, equaling 1.25 kA for each kicker plate or 2.5 kA through thyratron [4]. An oscillogram of the current pulses on the kicker plates is shown in Fig. 4. Half-sine pulse duration was about 160 ns.

The prototype demonstrated good operation stability. Therefore, we decided to place an order with the manufacturer.

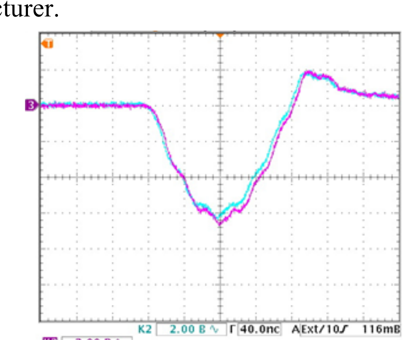

Figure 4: Current pulses on left and right plates of kicker. (The dividing coefficient is 200).

Factory Generators

The production of new generators was carried out by "Pulse Systems" Ltd [5].

New generators include DC HV source PS700C, non-inductive resistor 1к, capacitor 20 nF, thyratron TPI1-10к/50 and its driver BS-TP/10-2 created in BINP [6]. It is needed charge voltage 18 kV to obtain max current 1.3 kA. Transit lines are HV cables with wave impedance 50 Ohm and lengths 2 m. As a matter of fact each generator consists of two boxes. One includes HV source and thyratron driver – electronic section. Another box includes thyratron and capacitor etc – HV power section. Boxes are placed in the hall of Siberea-2 as it's shown in Fig. 5.

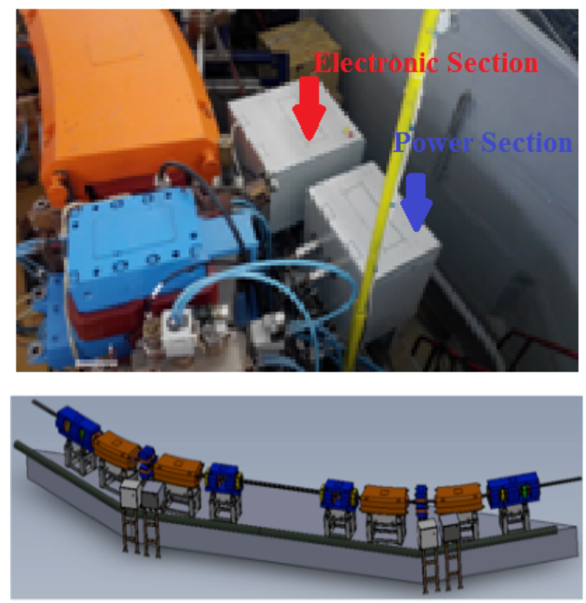

Figure 5: Generator units and 3-D model of new generators placement.

We developed all software needed for generator control via CAN interface. By software we control all thyratron parameters (e.g. voltages of two hydrogen generators, current of glow discharge, switch off/on of all driver channels and drivers itself) and parameters of HV power supply. Thus we do not need visual control of the generators. Length of CAN network is about 100 m. Synchronization system was modified for new mode operation as well.

In the normal mode operation the thyratron TPI1-10k/50 does not conduct a current in inverse direction. We used this feature to simplify the scheme of prototype, that's why we did not consider possibility of discharge diodes installation in order to prevent breakdown. But occasionally the thyratrons of industrial-made generators conduct a current in inverse direction as it is shown in Fig. 6. In our opinion the reason is in different HV power supply used in prototype and factory generator. As was mentioned we used a pulse power supply for the prototype but in the industrial generator is used DC power supply. Thus an exposition time of high voltage on thyratron anode influences on its stability. The pulse of

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the current as such as shown in Fig. 6 leads to complete loss of storage beam in the storage ring. From our tests with new generators we discovered that thyratron operation is performed without "negative" breakdown if charge voltage is less than 11-12 kV. For some reasons we did not consider a possibility of discharge diodes installation in order to prevent breakdown.

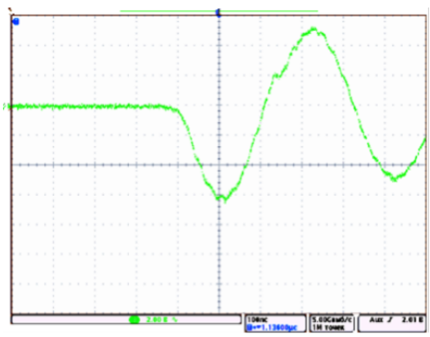

Figure 6: The current pulse while unstable thyratron operation. Charge voltage is 18 kV. (The dividing coefficient 200).

Thus to achieve stable operation of thyratron we needed to increase the pulse duration till 1 μsec that equal to 2.5 revolution period. However the calculation showed that it shouldn't affect the injection efficiency and the electron beam storage stability [7]. We added to our circuit 2 Ohm damping resistors for increase damping decrement. The charge capacity level is made 0.1 μF. The final scheme of new generators is shown in Fig. 7.

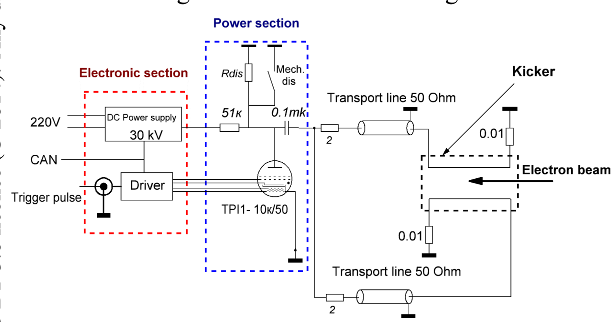

Figure 7: The final scheme of new generators.

R_{dis} is about several MOhm in Fig. 7. Transport lines lengths are less than 2 meters.

The test in the injection mode of Siberia-2 with new generators demonstrates that max. injection efficiency factor from Siberia-1 to Siberia-2 is obtained at 10 kV for "kicker" and 7 kV for "prekicker". Relevant oscillogram is shown in Fig. 8. The oscillogram corresponds to working parameters at injection process. Time shift between pulses are defined by distance between kickers, and, also the length differences of transit lines.

RADIATION LOAD ON THE NEW GENERATOR COMPONENTS

As it was mentioned the new generators are placed near kickers in the tunnel of Siberia-2. Despite the fact that electronics and PS unit of pulse generators are little below

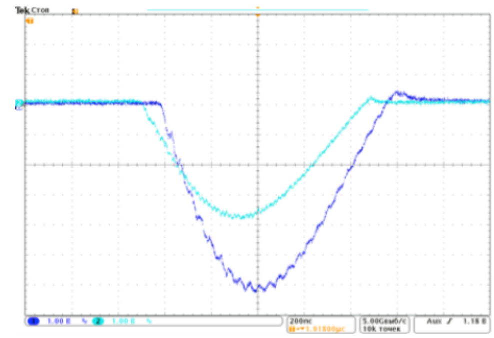

Figure 8: The current pulses on kicker and pre kicker plates. (dividing coefficient 200).

the median plane we have tested the radiation background. We made a rough estimation of the radiation dose for more than two years operation of new generators. The values of background radiation in units of "kicker" and "prekicker" generators are 0.88 Sv and 0.55 Sv respectively. For that period of time we didn't see any degradation of thyratrons or electronics.

CONCLUSION

The performance of new generators showed that current deflection mode for injection in Siberia-2 significantly simplifies the use of injection system. It allows to get more stable factor of injection efficiency up to 70% that is the same as it was with old generators operation. It should also be noted that for more than two years of new generators operation no significant maintenance had been carried out.

ACKNOWLEDGMENT

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