Pseudospark switches commutation depending on trigger characteristics

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Abstract. The commutation characteristics of TPI-type pseudospark switches, depending on the parameters of trigger circuits, are studied. An influence of the trigger pulse rise time on the pseudosparks time jitter is explored. It has been shown that the pseudospark switches can be triggered on a pre-ionization electrode with a cathode and a grid, simultaneously grounded. The double and the triple gapped deuterium and hydrogen switches were explored. The time jitter values of 1-2 ns on the deuterium switches triggered on the pre-ionization electrode have been achieved.

1. Introduction

The 20 MeV, 2 kA induction linear accelerator LIA-20 is developed in BINP. It can operate in a triple-pulse mode. To supply the induction cells of the linac, the pulse modulators are used, which provide 21 kV pulses of 60 or 360 ns duration \cite{1}. The modulator’s switches are the TPI-type cold cathode thyatrons or the pseudo spark switches ranked at 50 – 75 kV anode voltage \cite{2}. One of the main questions of the thyatron operation in the LIA’s pulse system is the time jitter.

2. Cold cathode thyatrons’s jitter statistics at LIA-2 facility

Earlier in BINP, the 2 MeV, 2 kA induction linac LIA-2 was designed that can be considered as a future LIA-20’s injector \cite{3, 4}. The LIA-2 has been used in VNIITF (Snezhinsk) for more than 6 years. For the LIA-2, about 100 thyatrons TPI1-10k/50 were tested. To control the thyatrons, a trigger board was designed in BINP, in accordance with manufacturer recommendations \cite{5}, figure 1.

The trigger board provides a complex thyatron’s power supply that includes a hydrogen reservoir DC power supply Ures with current stabilization, a pre-ionization arc discharge power supply UDCpretrig that is turned on for 50-100 ms, a pulse pre-ionization 3 kV power supply Upretrig that is turned on 500 – 800 ns earlier than a main grid 3 kV pulse power supply Utrig. Such complex control allowed to achieve a quite stable thyatrons commutation. 100 thyatrons’s jitter statistics are presented in figure 2. As you can see, the most thyatrons operate with the jitter of about 5 ns, although there are a lot of devices with a lower and bigger jitter.

3. Single pre-ionization pulse thyatron control

In the LIA-20 facility, it is proposed to use few hundreds of thyatrons, so it is desired to simplify a thyatron control and keep the jitter at the same level or better. In collaboration with IHCE (Tomsk), it was found that it is possible to control the thyatrons with a grounded grid and a cathode with a single
trigger pulse applied to a pre-ionization grid and keeping a pre-ionization auxiliary arc discharge (figure 3).

Figure 1. Principal schematic of double-pulse thyratron control with electrodes indicated: A – anode, C – cathode, Gr – gradient, G1 – grid of a pre-ionization, G2 – main grid.

Figure 2. Statistics of LIA-2 thytratrons’s jitter.

An advantage of such control is a much lower voltage spike applied to the trigger board circuits due to thyratron high current conduction. It can be explained due to a smaller part of an anode current that flows to a pre-ionization grid which is well shielded. For example with a main grid triggering (figure 1), a voltage spike amplitude can overstep 10 kV value during self-triggering of the thyratron that may lead to a trigger board failure. From the other hand, there is a question about a reliability of the thyratron switching-on process using a pre-ionization grid triggering. In that case, a grounded main grid is a potential barrier for the charge carriers which are supposed to penetrate from cathode part of the thyratron to an anode one, to provide a stable switching-on. Nevertheless, using the pre-ionization...
grid triggering with the grounded main grid and the cathode, a quite stable thyratrons switching-on process with an average 5 ns jitter has been achieved.

4. Thyratron switching-on stability depending on trigger parameters
The thyratron switching-on stability, using a double-pulse control (figure 1), was studied depending on the trigger and pre-trigger pulses voltage amplitude measured at the trigger board output. The data taken at a 3-gapped hydrogen thyratron test are presented in table 1. It is possible to lower the thyratron jitter from 10 to 1 ns rising the trigger pulses amplitude. A rise time of the trigger and pre-trigger pulses was about 35 ns. A main grid current Itrig was measured using a limiting resistor Rlim = 680 Ohm.

| Upretrig (kV) | Utrig (kV) | Itrig (A) | jitter (ns) |
|---------------|------------|-----------|-------------|
| 1             | 1          | 1.3       | 10          |
| 1             | 2          | 2.6       | 2.5         |
| 1             | 3          | 3.9       | 1.5         |
| 2             | 3          | 3.9       | 1.3         |
| 3             | 3          | 3.9       | 1           |

We also have studied the influence of the trigger parameters on the thyratron switching-on process in a single-pulse trigger schematic shown in figure 3. It was discovered that rising a trigger pulse slope value from 30 to 100 kV/µs, the thyratron’s jitter was getting much shorter - from 10 to 2 ns.

| dUtrig/dt (kV/µs) | Utrig (kV) | jitter (ns) |
|-------------------|------------|-------------|
| 30                | 3          | 10          |
| 100               | 3          | 2           |

For both considered approaches of the thyratron control, the following conclusion can be made. The thyratron switching-on process stability depends on the value of trigger grid current in a time interval. A higher current corresponds to a larger quantity of the charge carriers extracted from a cathode zone of the thyratron to an anode one that makes the switching-on process more stable.

Also, it can be mentioned that, using a new trigger approach, the different thyratron modifications were tested: such as the 2-gapped and the 3-gapped hydrogen and deuterium devices. The pre-ionization grid trigger parameters are: Utrig = 3.8 kV, dUtrig/dt ~ 30 kV/µs. An absolute jitter value depends on a thyratron type and can vary from 2 – 3 ns to 10 – 20 ns for various species in a batch. In the course of testing of over 40 thyratrons, it was observed that the 2-gapped devices have a lower jitter than the 3-gapped ones. On the other hand, the deuterium devices have a lower jitter than the hydrogen ones with the same design. It can be explained by that the deuterium thyratrons can be operated at higher levels of a gas pressure where a better switching-on stability is provided. Hereinafter, it is proposed to develop a more preferable thyratron’s design to provide the jitter insignificantly depending on different species in a batch.

5. Summary
The cold cathode thyratrons are quite simple to control. With proper trigger parameters a good switching-on stability with jitter of 1 – 2 ns can be provided.

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