THE MODULATOR FOR THE 10 MEV 2 KA INDUCTIVE ACCELERATOR PULSE POWER SUPPLY

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Abstract

For the 10 MeV 2 kA electron inductive accelerator pulse power supply the modulator prototype operating in two-pulse regime has been developed. The modulator is used for the resistive-inductive load supplying with the pulse voltage 20 kV, current up to 10 kA, 300 ns pulse duration. The data obtained at the nominal modulator operation regime are presented. The basic technical developments of the modulator parts and the modulator design are described.

INTRODUCTION

Today the task of the power x-ray facilities development for the different fast processes investigation is become urgent more and more [1, 2]. As a result of BINP and VNIITF joint efforts the paper project of power multi-direction multi-pulse x-ray source with minimal beam cross-section and maximal brightness has been elaborated. The project called LIU-10R was based on linear induction accelerator provided 2 kA electron beam acceleration up to 10 MeV, with accessible upgrade up to 20 MeV.

In accordance with the technical requirements the x-ray facility has to operate in the multi-pulse regime. The project base version provides two-pulse operation with the time interval adjustable from 2 to 10 μs. The LIU pulse power supply modulator development has been carried out with taking into account the following requirements:

Energy of the accelerated electrons 10 MeV

Duration of the electron pulse 300 ns

Amplitude of the electron current 2 kA

Stability of the electron energy ± 1%

The modulator features and test results in two-pulse operation are described below.

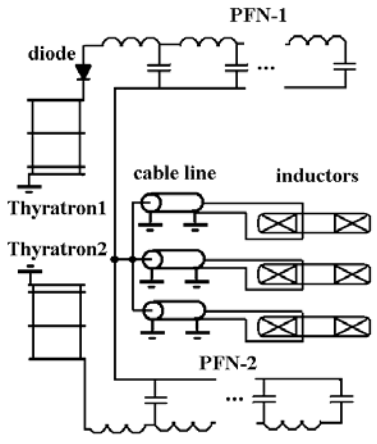

Figure 1: The modulator design with two PFN connected in parallel.

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THE TWO-PULSE LIU POWER SUPPLY PROPOSALS

As the basic variant of the two-pulse LIU inductors power supply system the modulator with the parallel pulse forming networks (PFN) connection commutated through the thyratrons was chosen (fig.1). In such a scheme the both thyratron cathodes are connected to the ground. It facilitates hydrogen reservoir and trigger supply, the design of the thyratron bus system seems more simplified too.

Due to the magnetic "diode" the isolation between two PFL is provided (see below). To increase the number of operation pulses it is enough to add additional items including PFN, thyratron and magnet diode.

As a result of the pulse power system careful investigation it was decided to supply three inductors in parallel from one modulator. To match the PFN wave impedance with the load each inductor is connected to the modulator through four parallel 10-meters 50-Ohm RK50-11-13 cables.

Table1: Designed modulator parameters.

Number of the inductors	3
Maximal current per each inductor	3.7 kA
PFN wave impedance	2 Ohm
Number of PFL cells	11
Cell capacitance (average)	10 nF
Cell inductance (average)	40 nH
Pulse top duration	300 ns
Pulse rise time 10-90%	80 ns
Pulse fall time 90-10%	150 ns
Maximal PFN charge voltage	45 kV
Pulse top voltage	20 kV
Pulse top voltage uniformity	± 1%

SWITCH PROPOSAL

As a high-voltage high-current switches for LIU modulator the hollow cathode thyratrons TPI1-10k/50 were chosen. This thyratrons called pseudospark switches provide commutation of the current up to 10 kA at the voltage up to 50 kV [3]. They are considered as alternative to common used high-voltage heated hydrogen thyratrons especially in high-current switching application with good stability and comparatively small average devise current. In comparison with the heated hydrogen thyratrons TPI-type switches have smaller dimensions, do not require water cooling, provide better time characteristics. Operation during 10^4 hours has showed advantages and some drawbacks of TPI1-10k/50 thyratrons [4]. As a whole, the test results let us conclude

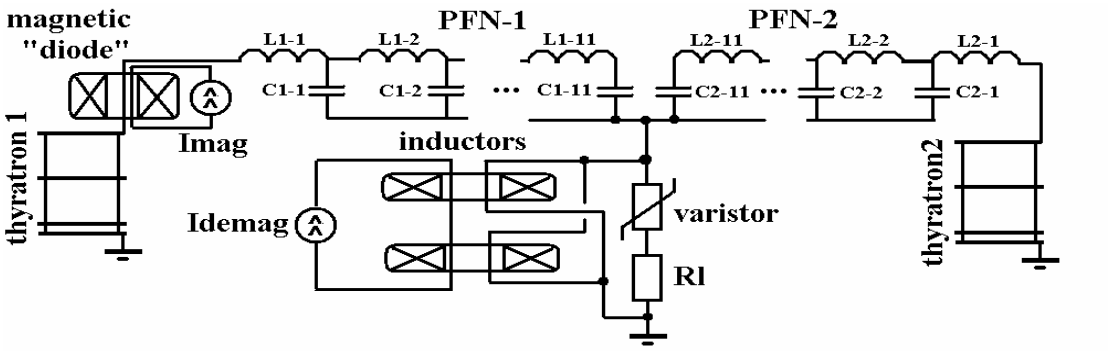

Figure 2: Test stand circuit.

that the TPI-type thyratrons, in particular TPI1-10k/50, are supposed to be strong alternative to modern high-current switches overriding them by many parameters.

CAPACITORS PROPOSAL

For the pulse generation of 3-5 s duration and 1 s rise time the capacitors performed with polypropylene dielectric, which has the best electrical characteristics at the current moment, are used [5]. Unfortunately the available polypropylene capacitors have the too big inherent inductance. At the same time it seems interesting to perform a strip line based on the polypropylene dielectric. Such the variant requires additional experimental investigation.

For the time present as the base capacitors for the modulator's PFN the glassceramic capacitors K15-10 were chosen. They have the following outstanding features:

- operational voltage up to 63 kV
- dielectric constant up to 1500
- inherent inductance less then 35 nH

PFN-TYPE MODULATOR

For experimental check of the main modulator's project ideas the following test circuit was implemented (fig.2, fig3). Here:

Rload = 1 Ohm, L1-1 = 100 nH,
L1-2 = L1-3 =…= L1-11 = 40±10 nH,
C1-1 = C1-2 =…= C1-11 = 10±2 nF;
L2-1 = 100 nH,
L2-2 = L2-3 =…= L3-11 = 40±10 nH,
C2-1 = C2-2 =…= C2-11 = 10±2 nF.
Idemag – the current source for the inductor demagnetization.

The part of the electron beam is played by the resistive load which comprises the array of the non-inductive disk resistors (Kanthal Globar) with equivalent resistance Rl = 1 Ohm and the array of the varistors provided the total stabilization voltage of ~6 kV (rear side on fig.3). The varistors simulate the diode properties of the electron beam. They have a low resistance at the high amplitude primary pulse and a high resistance at the low amplitude reverse pulse.

The two cores made of the 2NSR alloy (AMZ, Russia) chosen for LIU-10R project simulate the inductive properties of the load. The cores with the outer diameter 500 mm, the inner diameter 230 mm and the width 25 mm was used (right side on fig.3).

The two pulse forming networks placed on the top and on the bottom of the common bus are performed with K15-10-4700 pF/50 kV capacitors. Each PFN has 11 cells, each cell comprises two capacitors connected in parallel.

Figure 3: Test stand.

The two thyratrons TPI1-10k/50 are connected serially to the first cell of each PFL respectively. The magnetic "diode" made of the permalloy 50NP is connected in series with the first PFN thyratron. The core of the magnetic "diode" is magnetized in the forward direction by the current source Imag, so for the first PFN discharge current flowing in the same direction the inductance of the magnetic "diode" is minimal. During the second PFN discharge the high inductance of the magnetic "diode" prevents the current flow into the first PFN in the reverse direction.

The 44 kV PFN charge voltage was set with taking into the account the voltage drop on the thyratron, the magnetic "diode" and the mismatch of the PFN's wave impedance with the load impedance.

The load voltage curves (Uload) taken during the single-pulse and the multi-pulse operation are presented on the fig.4 and fig.5 respectively. To decrease the reverse

pulses duration down to 1.5 s the demagnetization current was set to 500 A.

CONCLUSION

Taking into the account the calculation and the test results one can conclude that the generation of the two pulses on the resistive-inductive load in accordance with the table 1 data seems possible. The magnetic "diode" provides good isolation between the pulse forming lines in the required time intervals. The next step of the modulator test will include experiments with the cable line and the real electron beam load.

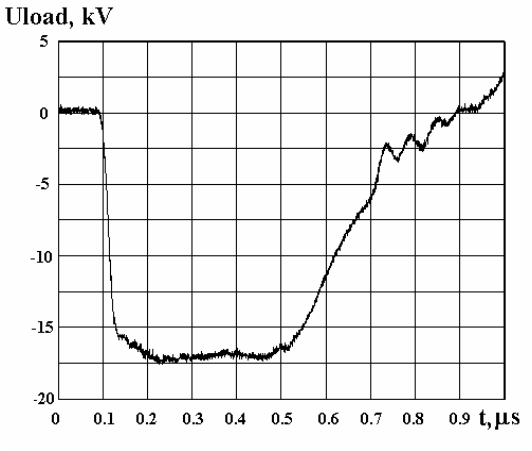

Figure 4: Load voltage pulse.

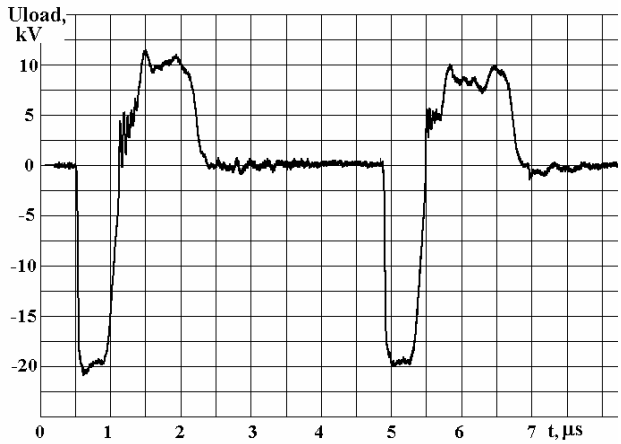

Figure 5: Load voltage pulses.

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