MARX GENERATOR GIN-1000 WITH 1 MV OUTPUT VOLTAGE AND 80 kJ STORED ENERGY

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The results of development and study of Marx generator with output voltage of 1 MV and stored energy of 80 kJ are reported. The measured value of generator inductance is ~1.3 μH, the measured effective ohmic resistance ~ 1 Ohm.

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INTRODUCTION

At RFNC-VNIIEF there are initiated works on creation of GAMMA multi-module facility meant to obtain bremsstrahlung radiation powerful pulses with maximal energy of quanta up to 2 MeV [1] over the area up to 1 m^2. It is supposed that the facility will consist of several similar modules; in each individual module the output voltage ~2 MV will be formed with the help of a double step-like forming line (DSFL) with water insulation [2]. DSFL will be initially charged up to the voltage ~1MV by two parallel connected equal capacitive energy storages – pulse voltage generators utilizing Arkadyev-Marx circuit.

The report presents a description of a generator developed for these purposes and gives the results of its parameter measurements.

1. CONSTRUCTION CHARACTERISTICS OF GIN-1000 GENERATOR

When creating GIN-1000 generator there was fully used RFNC-VNIIEF experience in such type generators' development. The design is based on developed earlier backbone units and elements such as 100 kV gas-filled gaps [3], liquid resistors, etc. At the same time when developing GIN-1000 there was an acute problem of limiting its inductance, for, to provide electric strength of water insulation, DSFL should be charged up to the voltage ~ 1 MV during the time not exceeding at least one microsecond. This required application of a number of new engineering decisions and going over to a more perfect element base. In particular, there were used more power-hungry and less inductive capacitors IEPM-100-0.4-UHL (as compared to IK100-0.4 capacitors) developed by Serpukhov Capacitor Plant (open stock company SCP "KVAR") in the frameworks of the agreement with "RFNC-VNIIEF".

Capacitors have the following characteristics: capacitance (0.4±0.04)μF, charging voltage up to 100 kV, inductance (50±20) nH, allowable discharge current from 50 to 100 kA, mass not more than 17 kg. To increase the generator reliability, it is supposed to use not more than 90 kV working voltage of capacitors charging. This determined the number of cascades of GIN-1000 generator that was accepted to be equal to twelve. To decrease the inductance of the generator discharge circuit, the cascades were connected as two parallel branches. In its turn, each of cascades represents two capacitors connected in parallel switched by a gas-filled gap. Controlled gaps of trigatron type are mounted in the first three cascades. A control high-voltage pulse of positive polarity is applied to trigger electrodes through liquid resistors, each of 300 Ohm resistance. To prevent the trigger system from returning high-voltage pulse generated at cascades operation, there is a 50 Ohm resistor at the generator input. Capacitors of cascades are charged by the negative polarity voltage through 1500 Ohm resistors. Discharge resistors and resistors connecting equivalent cascades in the parallel branches have the same characteristics. GIN-1000 generator is mounted in the metallic case filled by transformer oil. The metallic case also provides a reversed current distributor of charge-discharge circuit of GIN-1000. The general view of generators is presented in Fig.1.

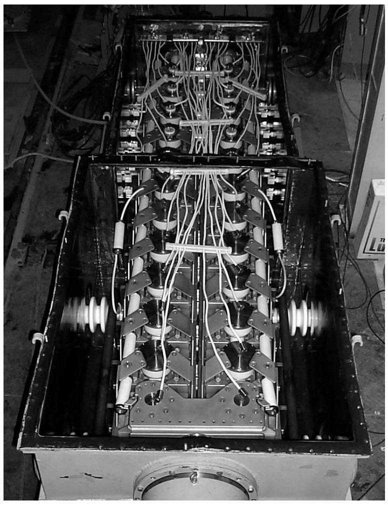

Fig.1. General view of GIN-1000 generator

2. MEASUREMENT OF ELECTROTECHNICAL PARAMETERS OF GIN-1000 GENERATOR

The main task of electrotechnical measurements was determination of inductance and ohmic resistance of discharge circuit of GIN-1000 generator. Moreover, the generator operation testing under the resistive load at the output voltage on the megavolt level was of significant interest. A measuring circuit at generator operation under a resistive load is shown in Fig.2.

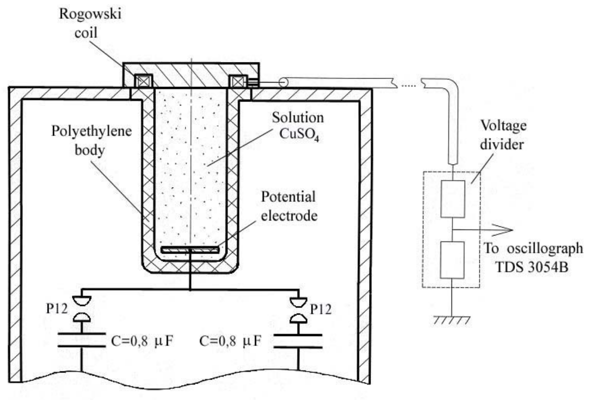

Fig.2. Measuring circuit at operation of GIN-1000 with resistive load

At operation in the short-circuit mode the generator's last cascade was directly connected to the case, i.e. instead of liquid resistive load there was mounted a short-circuiting metallic cylinder (a shorting jumper). When designing a shorting jumper, its dimensions were selected such as its inductance corresponds approximately to inductance of the output device connecting GIN-1000 with DSFL. Due to this fact it is supposed that the measured generator inductance in the discharge short-circuited mode would not differ strongly from the inductance of GIN-1000 discharge circuit connected with DSFL. Generator gaps were filled by a gas mixture of SF_6 and N_2 up to the pressure ~ 6 10^5 Pa, SF_6 content in the gas mixture was about 33%. At such filling of gaps GIN-1000 was triggered stable without failures at the cascades charge voltage within the range from 70 up to 90 kV. The delay of GIN-1000 triggering measured from the moment of trigger pulse voltage maximum up to the moment of current emergence in the load (a shorting jumper or a resistive load) was (120 ± 20) ns. The generator discharge in the short-circuit mode is of oscillation character, the current curve has a form of damped sinusoid. The period of current oscillations during the entire discharge remains practically unchanged and lies within the limits from $2.6\cdot10^{-6}$ to $2.7\cdot10^{-6}$ s; the damping factor $\beta = R/2L$ determined by the first two periods of oscillations equals to $(0.28 \pm 0.01)\cdot10^6$ s^{-1}. Basing on these data taking into account that the generator capacitance "in shock" is $0.133\cdot10^{-6}$ F there was determined inductance of discharge circuit of GIN-1000, L=$(1.33\pm 0.05)\cdot10^{-6}$ H. Besides, by current oscillograms there was calculated a dependence of circuit resistance on time, Fig.3.

Hereof the effective ohmic circuit resistance for the first semi-period of current oscillations can be obtained, R_{eff} =(0.95 ± 0.10) Ohm. When working with resistive loads the modes of discharge with possibly highest voltage at the GIN-100 output are the most interesting.

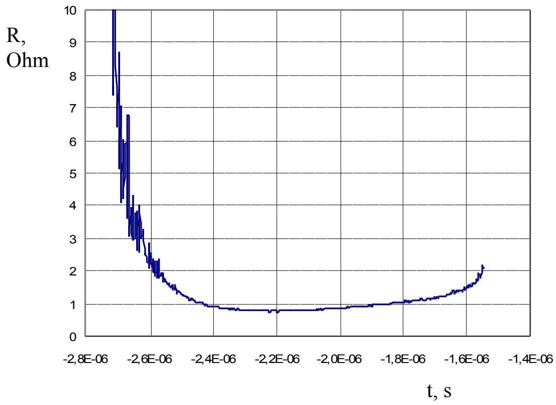

Fig.3. Dependence of circuit active resistance on time at discharge of GIN-1000 for short-circuit

A specific feature of utilized electrolytic loads is the fact that the load resistance $R_l(t)$ decreases greatly during discharge. That is why to obtain the possibly higher voltage on the output, one had to select such an initial resistance $R_0 = R_H(0)$ that at the moment of current peak the resistance $R_l(t)$ still remained high enough. At the same time, the top value of R_0 is limited, for by the moment of output voltage peak the ohmic resistance of gas-filled gaps should already be low enough, Fig.3. The optimal value R_0 determined in such way was about 12 Ohm.

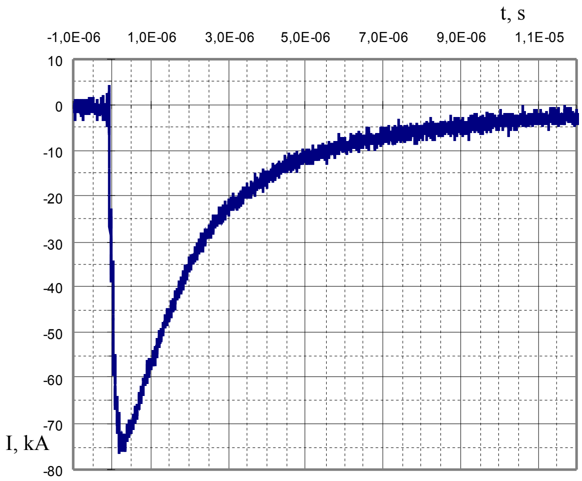

Fig.4. Oscillogram of discharge current for the resistive load R_0 = 12.4 Ohm

Fig.4 shows a corresponding curve of discharge current at the charging cascade voltage U_0 = -90 kV. The peak value of output voltage U_{out} estimated by processing of current oscillograms by the formula:

$$U_{out} = -L\frac{dI}{dt} - (12U_0 - \frac{1}{C}\int Idt) - IR,$$

was about 0.8 MV. Intrinsic ohmic resistance of generator was accepted as one ohm (R =1 Ohm) when calculating $U_{out.}$

CONCLUSION

There was manufactured and tested the GIN-1000 generator with output voltage ~ 1 MV and stored energy of 80 kJ. The inductance of generator was ~1.3 µH, effective ohmic resistance ~1 Ohm. There was confirmed the possibility for utilizing the similar generators for megavolt charging of DSFL of GAMMA facility module. The measured parameters testify that two such generators can charge DSFL for ~ 0.9 μs; the relative value of losses at energy transmission from two generators to DSFL is about 30%.

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ГЕНЕРАТОР МАРКСА ГИН-1000 С ВЫХОДНЫМ НАПРЯЖЕНИЕМ 1 МВ И ЗАПАСАЕМОЙ ЭНЕРГИЕЙ 80 кДж

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Приведены результаты разработки и исследования генератора Маркса с выходным напряжением 1 МВ, запасаемой энергией 80 кДж. Измеренное значение индуктивности генератора составляет ~1,3 мкГн, измеренное эффективное омическое сопротивление ~1 Ом.

ГЕНЕРАТОР МАРКСА ГІН-1000 З ВИХІДНОЮ НАПРУГОЮ 1 МВ ТА ЗАПАСАЄМОЮ ЕНЕРГІЄЮ 80 кДж

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Наведено результати розробки і дослідження генератора Маркса з вихідною напругою 1 МВ, що запасає енергією 80 кДж. Виміряне значення індуктивності генератора становить ~1,3 мкГн, виміряний ефективний омічний опір ~1 Ом.