Generator of high-voltage impulses of nanosecond duration on the basis of double-forming line

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Introduction

High voltage impulse generators of nanosecond duration are widely used for installations of power pulse lasers, for fast heating plasma, for generating of power electronic beams and for carrying out of experimental researches [1].

Recently interest to use of sources of high pulse voltages for application in devices of environmental, metrological, ecological, medical purposes, for electromagnetic compatibility and insulation co-ordination problems has increased.

Necessity of a high voltage impulses source of nanosecond duration range for simulation of electromagnetic disturbances, metrological purposes and in devices for immunity tests of objects subjected to electromagnetic impulses arising at lightning impacts, nuclear explosion, static electricity discharges, etc., is evident.

New methods of medicine on the basis of modern technologies require reliable and safe devices on the basis of a source of high voltage pulses with adjustable parameters of amplitude and metered duration in nanosecond range and frequency of recurrence within the limits of several Hz.

In experimental installations on gas cleaning with the use of impulse voltages to obtain an intensive corona in the reactionary chamber, as a rule, special cable generators based on voltage multiplication due to connection of cables in parallel at charging terminals and in series at the part of the reactionary chamber are used [2].

Existing designs of such generators practically do not allow creating installations with realization of effective parameters. Shortcomings of these generators: distortion of the form of the rectangular pulse due to effect of induction of shells and cores of cables, impossibility of obtaining front duration of pulses less than 10 nanoseconds, strong electromagnetic radiation, complexity of matching of the generator with load arrangements. For providing of comprehensible productivity of installations it is necessary to form pulses with high repetition frequency of ~10^3 Hz, that in itself is a challenge [3].

Above-mentioned sources of precise controlled voltage amplitude in a wide range should create pulses with the form close to rectangular, with front in the range of 1-5 nanoseconds at pulse duration of longer than 30 nanoseconds. Generators now designed on the basis of the coaxial cables connections making the forming line, as a rule, operate with the matched load. Their obvious disadvantages: reduction of amplitude of output impulse twice in comparison with the value of charging voltage of a forming line; complexity of obtaining fast switching (impulse formation with the

front of 1-5 nanoseconds at high voltage) of the energy store line; difficulties of matching of elements having frequency characteristics allowing with the minimal error to define parameters of the formed rectangular impulse.

Description of the generator

The generator is intended to obtain high voltage impulses of nanosecond duration range with the maximal amplitude up 150 kV and the impulse shape form close to rectangular with the duration up to 100 nanoseconds and front duration not exceeding 1-5 nanosecond. The generator total internal resistance is 75 Ohm. Frequency of pulse repetition - up to 10^3 Hz.

The principle scheme representation of the generator is given in Fig.1. The impulse double-forming line represents a special coaxial cable structure having a central core 3, an intermediate electrode 2 and an external shield 1. The sections 1-2 and 2-3 of the impulse double forming line have the same insulation and wave impedance of 37.5 Ohm. To obtain the equal wave impedance of inner and outer sections $Z_{12}=Z_{23}$ the following condition should be fulfilled (neglecting the thickness of the intermediate electrode 2):

$$S_2=S_1\cdot(1+S_1/r_1),$$

where S_1 – the distance between internal core 3 and intermediate electrode 2, S_2 – the distance between intermediate electrode 2 and external shield 1, r_1 – radius of the central core 1 (Fig.1).

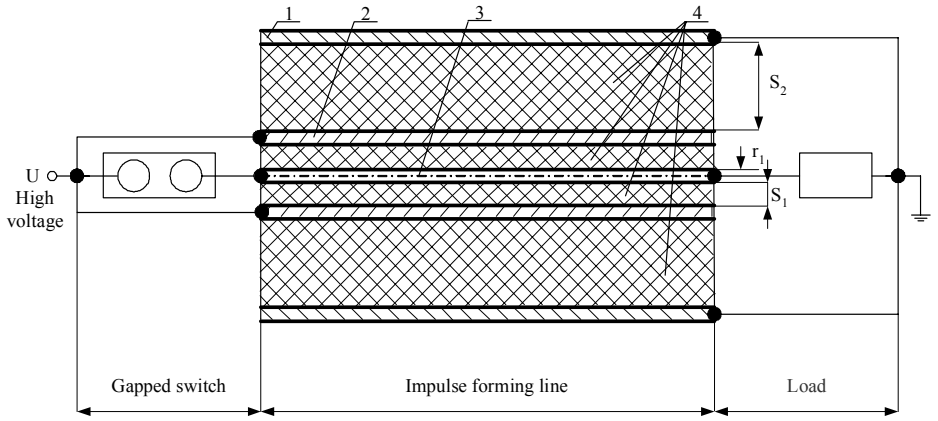

Fig. 1. The principle scheme representation of the generator.

The length of the impulse forming line and electric permeability of insulation determine duration of the impulse. Charging high voltage of the required value is applied to the electrode 2. Between the central electrode – cable core conductor 3 and the electrode 2 at one side of the impulse double-forming line there is a replaceable switch, and at the other side (between the central electrode 3 and the external shield 1) is connected the load. After triggering of the gapped switch in the space between the central electrode 3 and the electrode 2 the chopped front voltage wave propagates along the line in the direction of the load side, and at the moment of wave front

reaching the load terminal of the double-forming line a high voltage impulse is formed on the load.

The duration of the impulse is equal to the double line run time of the electromagnetic wave in the line-load matched mode. The switch and the load are attached to the impulse forming line by the coaxial sockets arrangement. The sizes of these elements are chosen in order to match their wave resistances with the wave impedance of the impulse double-forming line: of the commutation switch - to the wave impedance of the forming line part between electrodes 2 and 3 (37.5 Ohm), of the load – to the wave impedance of the forming line part between electrodes 1 and 3 (75 Ohm).

The impulse double-forming line is constructed according to the standard manufacturing technology of production of high voltage impulse cables of high dielectric withstand strength (with presence of semiconducting layers in insulation directly attached to electrodes).

Depending on the generator designation the application of different switches can be used. The required current switch should have the following parameters: the amplitude of the switched current is in the kiloamperes range with nanosecond duration switch time, the voltage is of the order of 100-150 kV, the high working pulse repetition frequency and the lifetime of the switch is thousands of hours.

For the generator intended to the electromagnetic compatibility tests and metrological purposes, it is planned to use a special modified multigapped switch – a commutator with subnanosecond time of switching at precise adjustable charging voltage unit, and for the loading – an attenuator with the resistance of 75 Ohm, which frequency response characteristics allow to determine main parameters of a measured high voltage impulse.

For the generator intended for flue gases cleaning, it is supposed to use multigapped switch operating with pulse repetition frequency of $\sim 10^3$ Hz. Researches of streamer corona discharge, which have been carried out by authors earlier, allow adjusting parameters of the impulse double forming line to the reaction chamber [4].

Charging by the constant output value high voltage unit, a special original design of the attenuator and the switch in their combination with the developed double-forming line will allow to obtain the tool for checking and calibration of high voltage impulse dividers and gauges of intensity of the impulse electromagnetic field.

The offered generator is intended to obtain the following characteristics:

- smoothly adjustable amplitude from 10 kV up to 150 kV;
- front duration in the range from 1 up to 10 nanosecond;
- discretely adjustable impulse duration from 10 up to 100 nanoseconds.

Conclusions

Creating of an optimal design of an impulse generator of nanosecond duration is possible by solving the following main tasks:

- formation of short front of impulse;

- reduction of influence of parameters and stray coupling between elements of the generator and reduction of electromagnetic disturbance emission in surrounding space;
- matching the generator with the load providing possibility to obtain high pulse repetition frequency (the problem of current commutation) and required operation life-time.

The solution of the above-specified problems is possible to achieve using of a double-forming line of coaxial cable design. Thus, practically all stored in the line energy is transferred into loading. It is necessary to take into account the energy consumption in the switch.

Advantage of the generator is a construction design of a path of pulse formation, which provides a possibility of operative replacement of elements: the energy store line, the commutation switch and loading with the help of specially developed high-voltage sockets. Such design allows using the generator as a source for devices of various purposes, including for the solution of such actual problems, as the normalized tests by nanosecond duration impulses; maintenance of metrological researches; in nanotechnologies; technology of cleaning of gas emissions; for processing of mineral oil; in medicine.

A charging unit working in the compound of the developed generator can have standard configuration and represent a ready industrial device. In case of use of the generator for the purposes of electromagnetic compatibility tests, metrology and medicine when frequency of voltage pulse repetition is rather low, it is preferable to apply charging unit having on the output terminals precisely adjusted voltage. For the generators intended for application for cleaning of gaseous emissions from ecologically harmful impurities, the most suitable will be traditional types of charging unit.

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