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# Multifunctional generator of high-voltage microsecond pulses

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A B S T R A C T

We have created a concept-developed high-voltage microsecond pulses generator. As evidence, we present graphs of the voltage produced by the generator operating at a fixed load. The generator has been developed in Shenyang Polytechnic University. The generator can be used for a variety of industrial and scientific applications, such as validation of electro-diagnostic and study of insulator's properties, creating a voltage in the plasma chemical reactor, the creation of electron beams and x-rays, pulsed power, microwave equipment, etc. The magnitude of the voltage and current to power the high voltage unit and a slew rate of supply voltage used to supply power to the high voltage unit of a conventional line type twisted pair cable instead of costly coaxial high voltage cable. Compact high-voltage output unit assembled according to the scheme with a step-up transformer and choke saturation, performing the function of a magnetic switch.

## 1. Introduction

Single shot based pulsed power generators with extremely high peak power have been developed for military and nuclear fusion applications. The size and weight of these pulsed power generators become larger and larger because of the increase in primary stored energy. Successful development of these large pulsed power generators has produced new approaches in military and nuclear fusion research. For example, electromagnetic launchers and inertial confinement nuclear fusion using X-ray radiation from Z pinched plasmas produced by pulsed power. The rapidly developing pulsed power technology and high-voltage pulsed generators have been widely applied in many fields such as electron beam accelerators, gas discharge plasma, ultra bandwidth (UWB) systems, dielectric material researches, etc. [1–7].

On the other hand, repetitively operated pulsed power generators with a moderate peak power have been developed mainly for industrial applications [8,9]. The primary stored energy is small in comparison with the single shot based pulsed power generators. The pulsed power outputs' reliability and quality are not the only important aspects. The lifetime of the pulsed power generator ia very important to achieve industrial applications with pulsed power. The pulsed power generator development, optimized for industrial applications, has stimulated research of many kinds of applications.

Traditional pulse generators cannot meet the requirements of high voltage, high repetition rate and fast rise-time any more [9]. The high performance pulsed power generators and their development have become a hot spot in the field of pulsed power technology.

The switch is the most critical component for a pulsed power supply. It plays an important role in system's operation, affecting factors such as rise-time, efficiency, repetition rate, lifetime, cost, etc. Available switches for systems with capacitive energy storage, which are primarily used, include semiconductor switches (MOSFET/IGBT), magnetic switches, spark-gap switches, etc. Semiconductor switches have a long lifetime and a high repetition rate (0.9–1.2 MHz), but their limited capacity and high cost for large-scale applications are the problem. Magnetic switches are robust and can be used for high repetition rates (up to 10 kHz). However, their energy conversion efficiency for short pulse generation is relatively low (typically 60-80%), and there is always a primary switch needed. The spark gap switch can hold a high voltage and carry a large current; it has low conductive impedance and is easy to construct. It is one of the most efficient and cost-effective switches for large pulsed power generation, while its lifetime is a limitation. Gas spark gaps were used in the majority of generators because of the facility, compactness, and fast switching speed. However, in terms of a long time repetitive operation, gas switches are likely to be limited by the electrode erosion, recovery characteristics of the insulation gas, and accumulation of the contamination produced in the discharge. Magnetic switches are well-known for high stability, reliability, repetition rate, and long operation time because of no electrode erosion or discharge recovery, namely – the long-term stable operation

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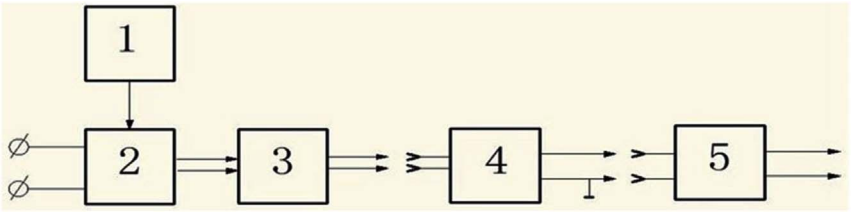


**Fig. 1.** Generator's block diagram: 1 – control unit, 2 – power block, 3 – a long line, 4 – output high-voltage unit, 5 – divider-load.

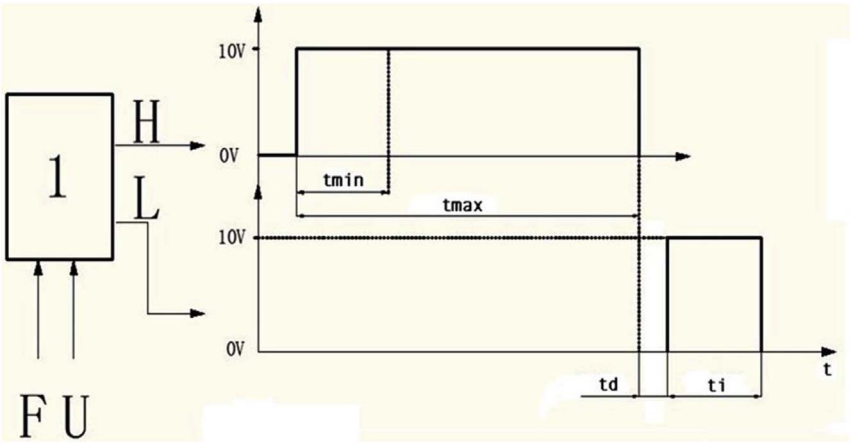


**Fig. 2.** The time diagram of the control unit's.operation.

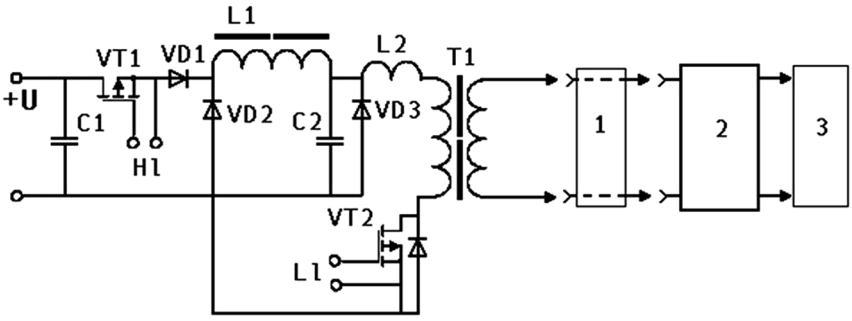


**Fig. 3.** A simplified diagram of the power (charging) unit: 1 – long line, 2 – output high-voltage unit, 3 - load-divider.

is a key requirement for industrial applications.

Currently, compact sources of pulsed low and medium power for industrial and scientific applications are the vigorously developing field of research.

Thus, there have been studies of magnetic switches employed for a high power, long pulse generator with low impedance.

## 2. Materials and methods

Magnetic switches are used in this paper and the links below are known for their stability, reliability, high repeatability of the impulses and long life compared to other types of switches. In terms of the answer switch and the magnetization reversal processes of the core, they also allow you to use as a preliminary obsticale pulse thyratrons and other semiconductor switches in modes that increase the reliability and lifetime of semiconductor devices and circuits in general. The current level scheme and technical solutions for the microsecond and sub-microsecond pulsed systems with magnetic switches designed for use on loads with different impedance and output power in the load are described in Refs. [10–13]. The above mentioned list contains systems with different power levels – from 0.5 TW to 1 MW, with different durations of the voltage pulses (from 10 ns to a few microseconds), and under voltage from 10 kV to 5 MV. These pulsed systems were developed to operate on different types of loads with different magnitudes of the output currents. In science and industry, application area for high-voltage generators of repeated pulses is also diverse and includes, for example, creation of sources of x-rays and fast particles for surface treatment [14,15], food processing, sterilization of food and medicine [13], ecological applications [16]. There are also possible future applications of pulsed power. In this paper, we drew our attention to the generator operating under the high-resistance capacitive load, used to simulate the gas discharger.

This article describes the high-voltage microsecond pulsed generator developed in the Shenyang Polytechnic University. The generator can be useful in testing or studying the dielectric material under low ($0.5 \div 5.0$ μs) voltage and high voltage amplitudes (about $50 \div 250$ KV), in plasma-chemical reactor, as well as the electronic beams and x-rays, pulsed power, microwave equipment, and other interesting fields of science and technology.

Technical gaps in transmitting short pulses over distances from a few meters and in any pressurized volume are well known, for example, in a cell with high pressure, etc., that requires impedance matching transmission line and load, and usually involves the use of high-voltage cables and the corresponding connectors. This problem can be circumvented by splitting the generator into two parts: the core and the external high voltage, used in the described device.

The main generator's feature is to transfer the energy on the “long line” under relatively low voltage (about 1500 V) and relatively low currents (up to 1000 A.) to charge the accumulator placed in the output block. Such structure of high-voltage pulsed generator