DESIGN OF THE PULSE GENERATOR FOR TESTING AND VALIDATING PARTIAL DISCHARGE MEASURING SYSTEMS

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Abstract: This article deals with the design and implementation of a pulse generator serving as a calibration generator for setting up measuring systems for monitoring the activity of partial discharges (PD) in the high-voltage power transformers or gas insulated switchgears (GIS). After installing the measuring device, it is advisable to test the entire measuring chain and, if necessary, set parameters that would affect the correct detection of PD signals. Calibration pulse generators are used for setting and validating measuring chain. These are usually used in systems that sense the electromagnetic activity of PD. Correct and timely detection of PD can avert a transformer accident and thus contribute to higher safety in power plants. The proposed generator should serve as the output part of a programmable generator, which did not reach sufficient parameters of output pulses. The goal was to achieve a rising time around 100 ps and an amplitude of more than 6 V using modern and very fast operational amplifiers and step recovery diodes as a sharpener of the input pulse. The measurements show waveform of the output voltage pulse.

Keywords: Pulse generator, partial discharge, UHF band, step recovery diode

1 INTRODUCTION

Pulse generators are used in the field of partial discharge measurement to obtain the most similar signal of the partial discharge. An important element of any measuring system for PD is also a pulse test generator, which verifies the functionality and settings of the entire measuring chain. Many different approaches are used to generate very short and steep pulses, these are described in the following chapters. The article will mainly deal with the design of a generator with a step recovery diode (SRD), which is the most suitable for verification and validating PD measuring chain in terms of parameters and required properties.

2 WHOLE DESIGN OF IMPULSE GENERATOR

The following chapter will describe the design of individual parts of the generator. A programmable generator will be described in more detail, which will serve as an exciter for the SRD. The pulse SRD generator itself will form the output part of the programmable generator, which, however, did not reach sufficient parameters of output pulses for the UHF band and was therefore unsuitable for PD simulations. In fig. 1 you can see the programmable generator fictional name "G1". The generator has three high frequency (HF) and ultra-high frequency (UHF) outputs. It is powered from the mains and can be programmed via USB cable using software on a PC. The software allows you to program different signal patterns and place them in a defined part of the mains frequency period. It is also possible to adjust the polarity of the signal.

Figure 1: Programmable generator “G1”.

Predefined patterns can be activated using the buttons on the generator. Unfortunately, a closer examination of the UHF output revealed that the output pulses did not reach the parameters of the PD pulses. The times of rising and falling edges of pulses were 5-7 ns, for the purpose of calibration of measuring systems for PD the output voltage was also small, maximum 2,8 V. The aim was to improve the existing G1 so as to maintain its main advantage - programmability but output pulses were as similar as possible to PD. Fig. 2 and 3 show the actual waveforms from UHF and HF output G1.

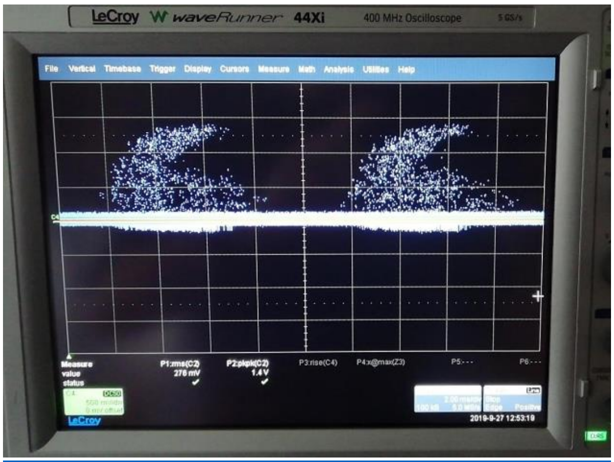


Figure 2: Chosen pattern replayed to a 50 Hz line-triggered oscilloscope with persistence display enabled (500 mV/div; 2ms/div).

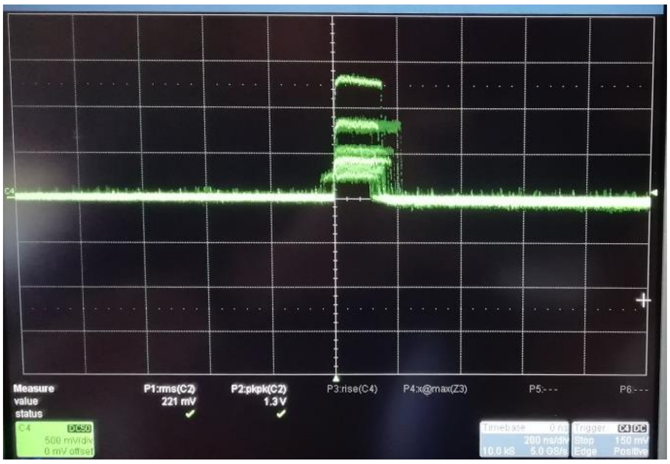


Figure 3: The individual pulses on the ‘HF’ output channel have variable amplitude (shown here with display persistence enabled, 500 mV/div). Pulse duration is about 150 – 200 ns (200 ns/div).

The individual parts of the SRD generator connection will now be described. Fig. 4 is a block diagram of the proposed generator.

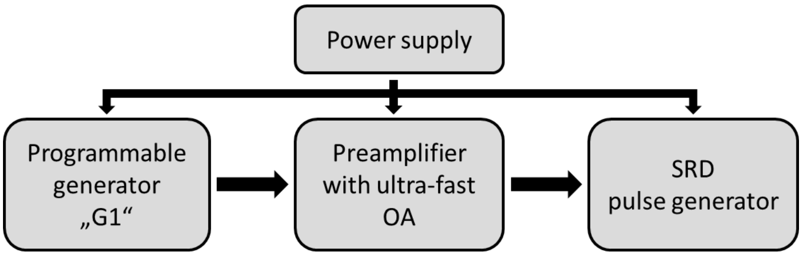


Figure 4: Block diagram of generator.

2.1 PREAMPLIFIER WITH ULTRA FAST OPERATIONAL AMPLIFIERS (OA)

To obtain the highest possible excitation voltage, a preamplifier from OA was included behind the generator G1. It is a two-stage non-inverting amplifier. The minimum required slew rate to transmit a signal with an amplitude of 8 V and a leading edge of 5 ns is

$$SR = \Delta V_{out}/\Delta t \quad (1)$$

where *SR* is the slew rate, ΔV_{out} is the output voltage, Δt is the rise time, after calculating we get 1600 V/µs. The leading edge of 5 ns corresponds to a frequency of 200 MHz both of these parameters were important for the selection of a suitable OA. Very fast operational amplifiers from Texas Instruments were chosen for the amplifier, which achieve a slew rate of up to 8000 V/µs and their bandwidth is 350 to 900 MHz. This ensures that the input signal from G1 is not distorted. Specifically, it is a type THS3491, which meets all required parameters with sufficient reserve. According to the manufacturer's recommendations [1], suitable sizes of feedback resistors were calculated and chosen. The first stage of the amplifier has a gain of 4x and the second stage 2x. The total gain is therefore 8x. Capacitors C14 and C19 have been added to limit the frequency band and prevent amplifier oscillation. Schematic is in figure 5.

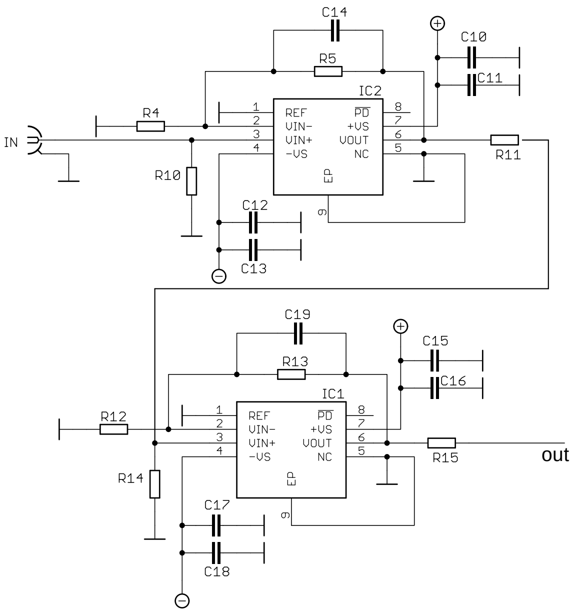


Figure 5: Schematic of preamplifier.

2.2 STEP RECOVERY DIODE PULSE GENERATOR

The second part of the design was a circuit with SRD. The SRD actually acts as a signal edge sharpener here. A pulse-forming network is also included in the circuit, which ensures a narrow

Gaussian pulse. We used the literature [2] and [3] to design the generator. The designs of the generator with SRD and their possible modifications and improvements are very well described here, [4], [5], [6]. The SRD connection contains a Schottky diode and delay line, which allows the generation of narrow Gaussian pulses, which increases the bandwidth of the generator. Another advantage of this involvement is the large ringing reduction. Schematic of SRD generator is on fig. 6.

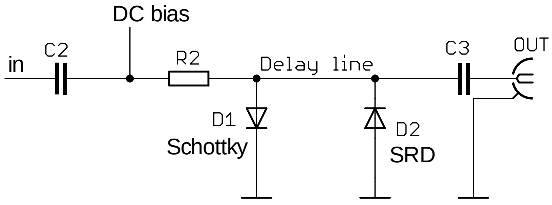


Figure 6: Schematic of SRD pulse generator.

Of course, the generator also includes a power supply. A laboratory symmetrical source was used for operational amplifiers and a linear stabilizer of the LM337 series, which is located directly on the PCB, was used to set the DC bias current of the SRD. The power supply of the operational amplifiers is ± 15 V. The fabricated and equipped PCB is shown in fig. 7.

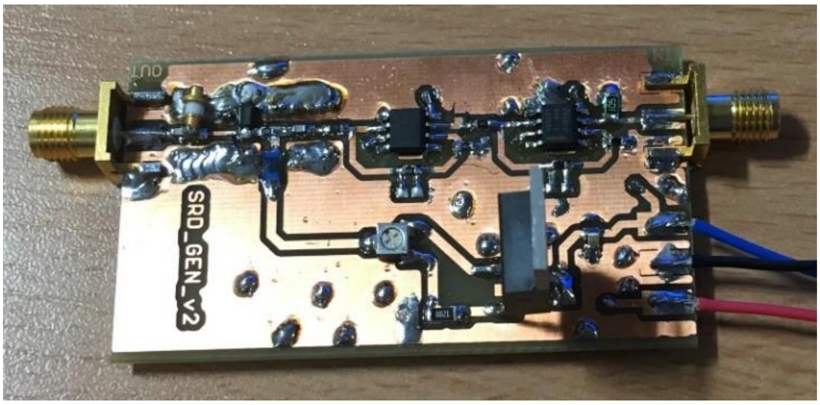


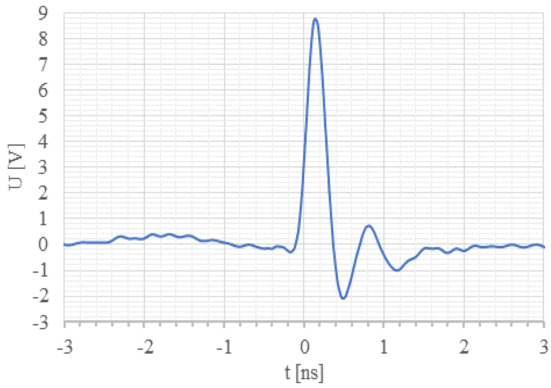
Figure 7: Complete PCB with SRD generator.

3 MEASURING ON IMPULSE GENERATOR

This chapter deals with measurements of output pulses from the generator. Both the laboratory generator and the G1 generator for which the proposed generator is intended were used for the measurement. A Tektronix TDS 694C oscilloscope (3 GHz, 10 GS/s) was used to measure the output waveforms. Unfortunately, the manufacturer did not state the time of the leading edge of the oscilloscope, but according to the sampling rate, we assume that it is around 90 ps. For completely correct results, it would therefore be appropriate to subtract this time from the measured leading edge.

In the first tests, the SRD generator was excited from the laboratory generator by rectangular pulses. The leading edge of the pulse was set to 7 ns and the repetition frequency was 3,15 MHz. After amplification, the control pulse had 12V. This corresponded to an output pulse of about 8,8 V and a leading edge without correction of 149 ps as seen in fig. 8 left part.

The last measurement was performed with the driving generator G1 to show that the output pulses from the SRD are dependent on the size of the control pulses. This confirmed the measurement, the pulses have different sizes according to the G1 programming, depending on the repetition frequency and the shape of the control pulses, the rise times of the output pulses also change slightly. The captured waveform is shown in fig. 8 right part.



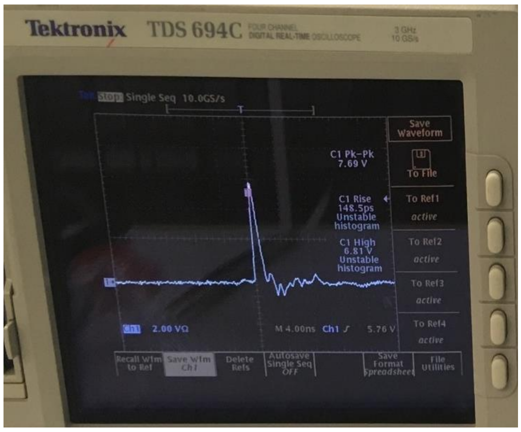


Figure 8: Measured output impulse of SRD generator (left), screenshot of SRD generator output impulse driving by G1 (right).

4 CONCLUSION

In this paper, we presented the design of an impulse generator as an additional part of the programmable generator G1, which is used to set and calibrate sensors for GIS or PD. The generator consists of a preamplifier with very fast operational amplifiers in a non-inverting circuit. The second part consists of a pulse generator with SRD and pulse-forming network. The whole device was realized and subjected to measurements. The measurement results show a maximum pulse amplitude of 11,5 V and a leading edge time after correction of the oscilloscope's own leading edge below 100 ps. The graph shows a slight but undesirable ringing, which may be due to the PCB material used or the imperfect PCB design. We have thus successfully improved the G1 programmable generator according to our ideas. Subsequently, further testing will take place during the calibration of GIS or PD sensors.

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