Pulse Generator with Diodes D2601NH 90T
at company Phoenix Contact

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Introduction

The market for pulse power applications is at present mainly dominated by the defence technology. Besides, there are increasingly industrial applications. Strong endeavours exist to replace the mainly used switches like spark gap, Ignitrons and Thyratrons with semiconductor switches. Among others, the availability of diodes with high blocking voltage and high reverse recovery characteristics property is required.

Application

The company Phoenix Contact has developed a pulse generator which is used for the test of surge current with lightning protection components (resistive behaviour). The simplified design of the pulse power installation is shown in illustration 1. The charging voltage of the capacitor C amounts up to 30 kV.

In the area of lightning protection facilities, there are two different tests. They are marked as 8/20 and 10/350 pulses. The waveform of the surge currents is shown in the illustrations 2, 3a and 3b.

The 8/20 pulse is defined with a rising edge of 8µs. During this time, the current of the amplitude rises from 10% to 90%. It fades away within 20µs to 50% of the amplitude value. With this pulse variation, the maximum amplitude of the pulse generator presently amounts to 80kA at present; an increase to ~100 kA is planned. Thus results a current gradient of $di_F/dt = 10kA/µs$ while increasing and a current gradient of $-di/dt = 4kA/µs$ while decreasing.

The so-called 10/350 pulse has a rising edge rate of 24µs in the Phoenix contact system. The maximum amplitude of the 10/350 pulse amounts to 68kA. Within 1ms, the current fades away with a relatively big time constant on 10% of the amplitude value.

Because of the relatively smooth fading away of the current, normal rectifier diodes can be put into the crowbar circle. In order to keep the number of diodes to be connected in series as low as possible, eupec has suggested 3'' diodes with 9kV blocking voltage, **D2601N90T**.

The blocking diodes are firmly turned off with the attempt of recharge of the capacitor C, i.e. with a high commutation rate against high voltage. At the same time, the reverse current of the diodes may not tear off.

Through the improvement of the turn-off behaviour of the rectifier diodes, eupec is presenting the most effective diode **D2601NH90T**.

Charge of the diodes

During the start-up of the installation, measurements of voltage were performed at the blocking diodes in order to appraise the charge of the diodes. It was fixed that the crowbar works as a freewheeling diode with both pulse forms. Due to parasitic inductance of the circle, the capacitor C recharges. Through the recharge attempts, the blocking diodes firmly switch off with a high di/dt against high voltage. The voltage variation is shown in the illustrations 4a and 4b.

The overshoot of the voltage at the turn-off of the blocking diodes (illustrations 4a and 4b) is caused by the off-state current gradient of the reverse current of the diodes and the inductance of the circle.

Technology of the diodes

In order to avoid high voltage overshoots at the blocking diodes, diodes with a higher softness-factor are required. I.e., even within high dynamic charge, the reverse current must softly subside. The reverse recovery behaviour of the diode **D2601NH90T** is shown in illustration 5b. For comparison, the reverse recovery behaviour of the Crowbar diode **D2601N90T** under the same measurement conditions is shown in illustration 5a. The steeper decay of the current after reaching the peak of the reverse recovery current can be clearly recognized. Additionally, the bigger generated voltage overshoot of the Crowbar diodes in relation to the blocking diodes can be seen. The high softness factor of the blocking diodes **D2601NH90T** is reached by an ion implantation. The forward voltage does not essentially increase itself, though the surge current remains stable.

The Crowbar diodes are normal rectifier diodes. The blocking voltage of 9kV and the diameter of the diode pellets of 76mm are important for an efficient construction with simultaneous minimisation of parasitic effects of the pulse generator. It requires no parallel circuits for 100kA/30kV and it limits the number of switching diodes connected in series to 4. Therefore, only 3 blocking diodes in serial connection are needed.
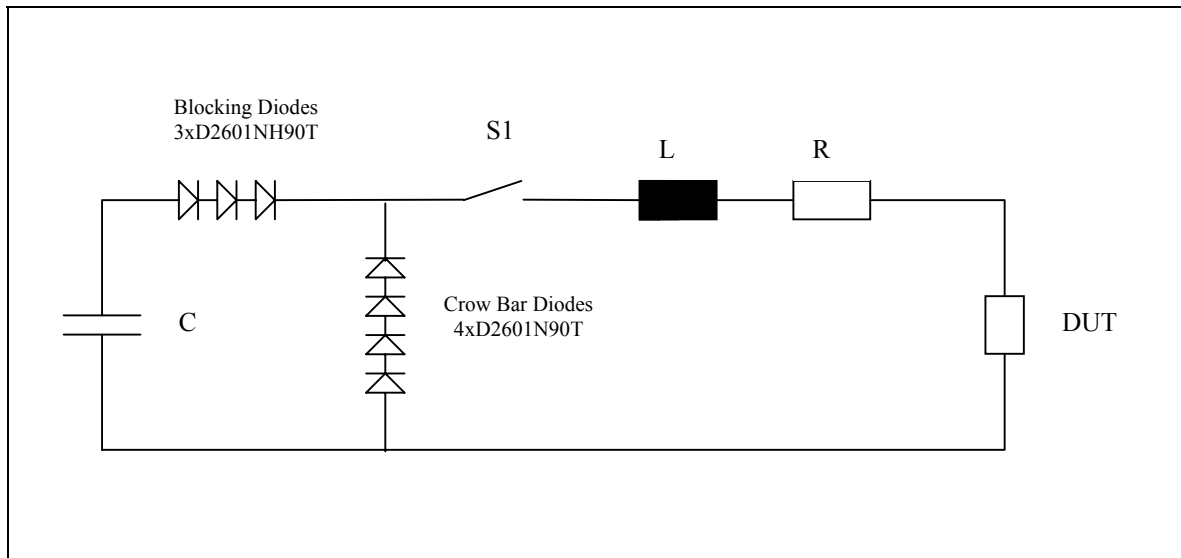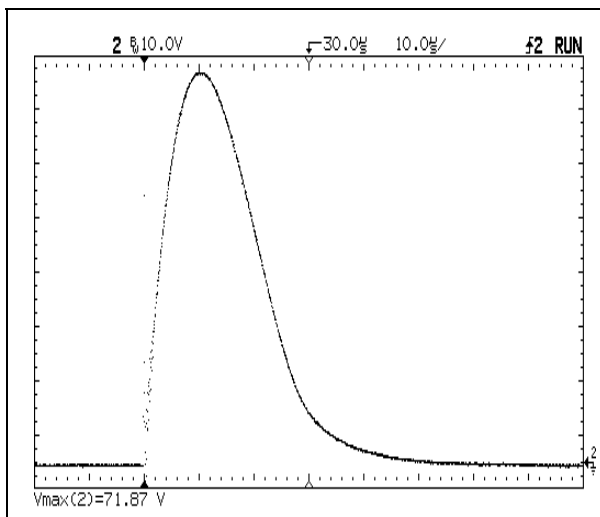
Illustration 1: Simple design of the pulse generator

Illustration 2: 8/20 pulse (10µs/div. – 10kA/div.)
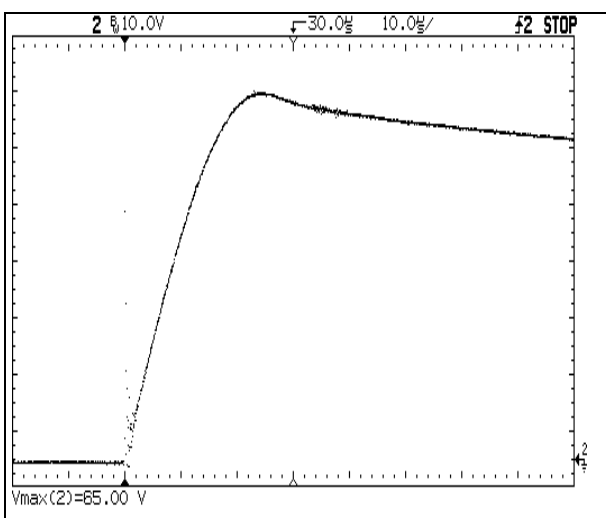
Illustration 3a) 10/350 pulse – increasing slope
(10µs/div. – 10kA/div.)
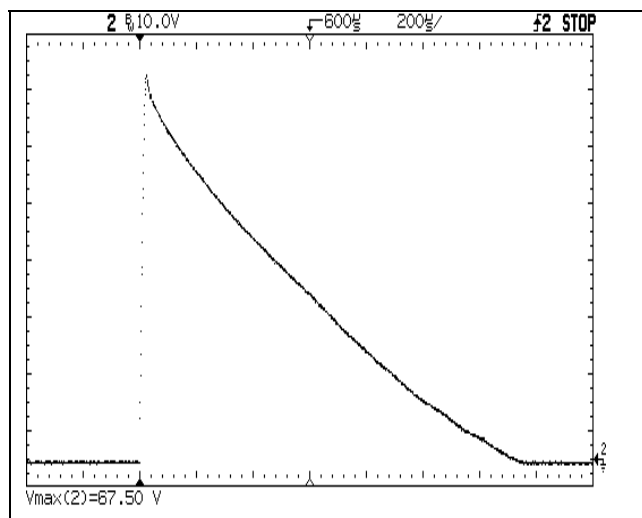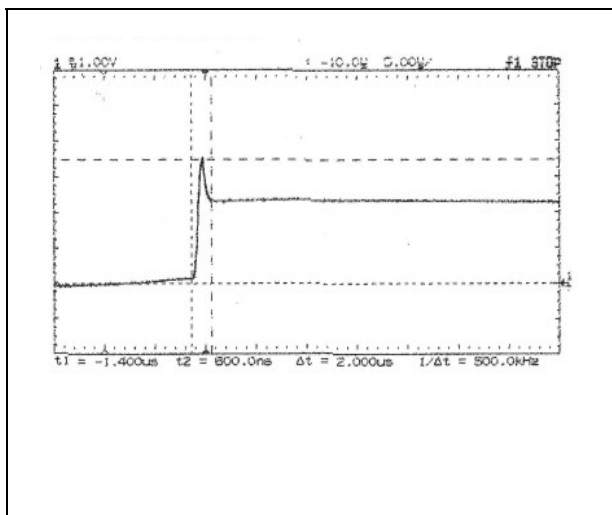
Illustration 3b) 10/350 pulse
(200µs/div. – 10kA/div.)

Illustration 4a: measured back voltage (V_R= 3457V)

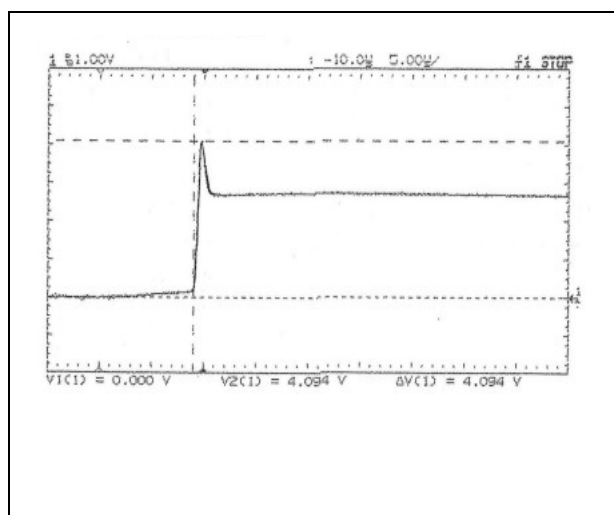decreased commutation of the blocking diodes of 35kA, 8/20 Puls, V_C = 15 kV

(5µs/div. – 1kV/div.)

Illustration 4b: measured back voltage (V_R = 4094V)

decreased commutation of the blocking diodes of 28,75kA ,10/350 Puls, V_C = 15 kV
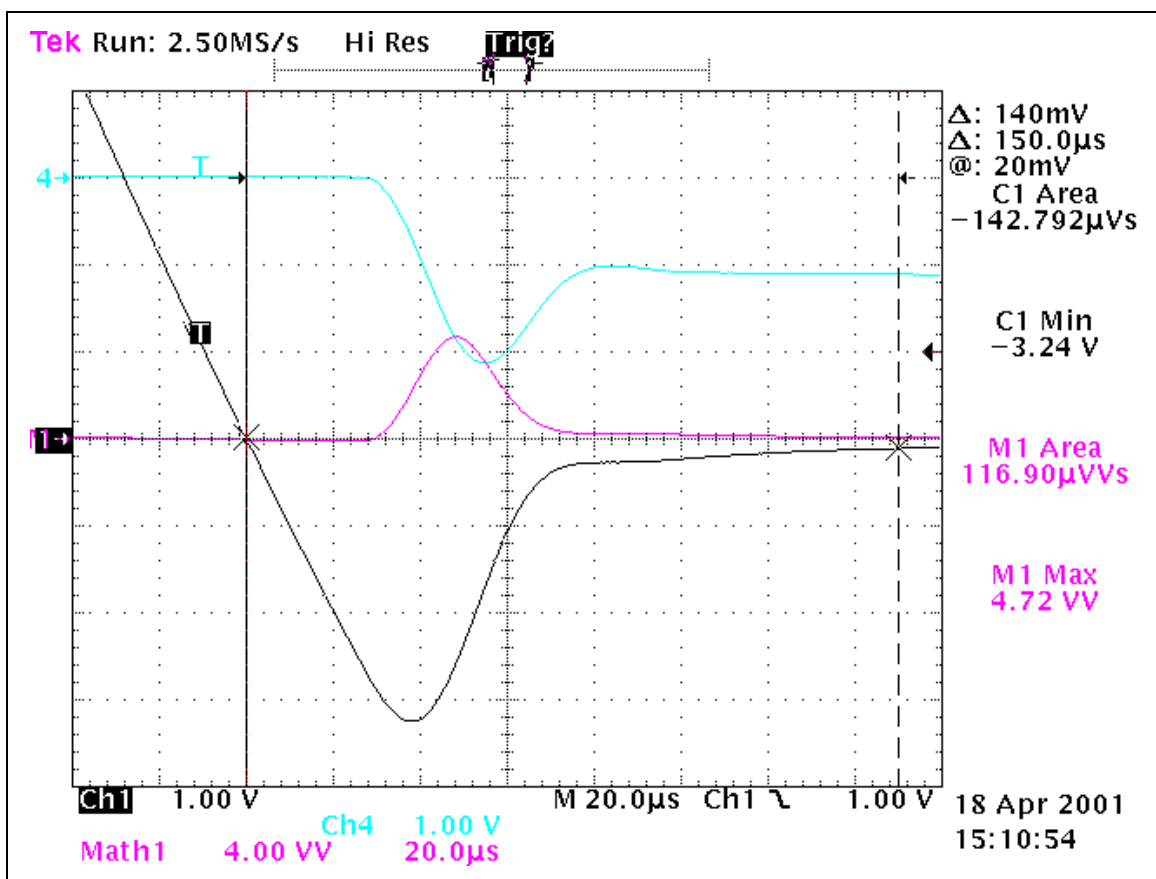
(5µs/div. – 1kV/div.)

Illustration 5a: Turn-off behaviour of the Crowbar diode **D2601N90T**

Ch1: I_F =>   100A/div.

Ch4: V_R =>   1000V/div.

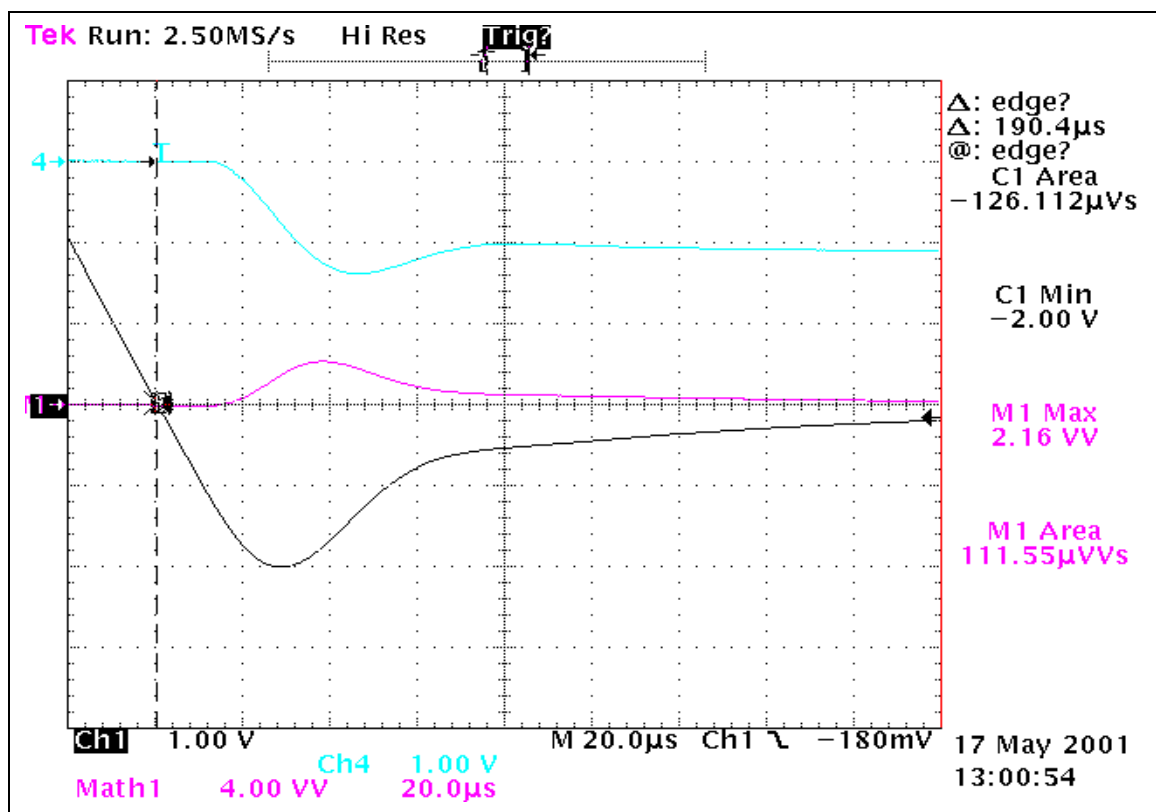Math1: P_{off} =>   0,4MW/div.

Illustration 5b: Turn-off behaviour of the blocking diode **D2601NH90T**

Ch1: I_F => 100A/div.

Ch4: V_R => 1000V/div.

Math1: P_{off} => 0,4MW/div.