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(Klystron)

THE EFFECT OF DIFFERENT RESISTOR VALUES ON THE CTF3 SUB-HARMONIC KLYSTRON PULSER SIMULATION CIRCUIT PERFORMANCE

Li SHEN

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The effect of different resistor values on the CTF3 sub-harmonic klystron pulser simulation circuit performance.

Li Shen[1]

1. Introduction.

This klystron pulser will be used for the CTF3 injector to provide a high-voltage pulse for the sub-harmonic L-band klystron. The klystron will operate at a repetition frequency of 10Hz with a peak voltage of 65kV and a pulse width of 2.5µs. The switch in the klystron pulser consists of a series array of IGCT solid-state switching devices and is modeled using an opening and closing set of switches. In this note we present the study of the effects of variation of the values of the clamping resistor R2, the filter resistance R4 (between the switch and the pulse transformer) and the anode spike absorber resistor R12.

2. Simulation of circuit performance.

The simulation circuit of klystron pulser is shown in Figure1, where all components are referred to the primary winding. A high-voltage step-up pulse transformer with a ratio of 1:13 is used. This transformer is modeled using the components L42, R5, L41 and C28. These are respectively, the magnetizing inductance, the core loss resistance, the total leakage inductance seen at the primary winding and the stray capacitance. The klystron model used is a voltage controlled current source with a series connected high-voltage diode to obtain a microperveance of two.

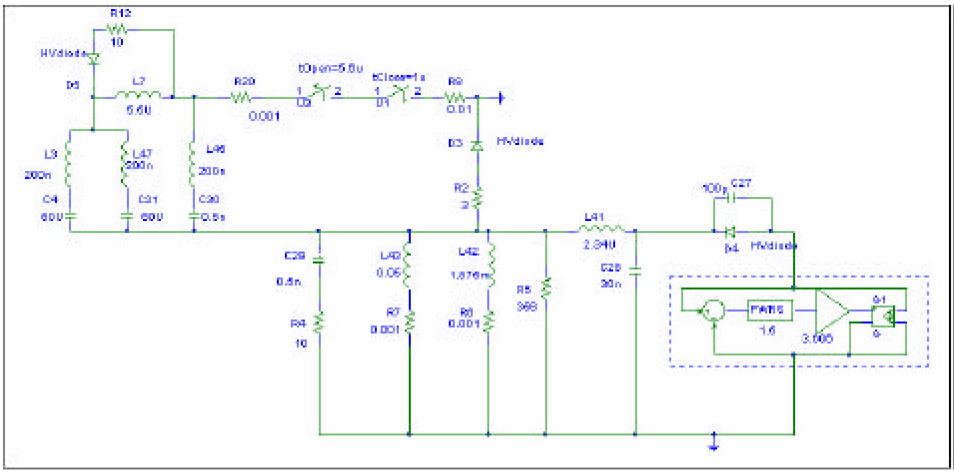

Figure 1: Simulation circuit of klystron pulser

[1] Visitor from BEPC, Beijing, China

In this circuit, R2 and D3 make up a clamping network protecting the klystron from any inverse voltage. R4 and C29 form a network that matches the impedance between the discharging circuit and the cable connecting the pulse to the klystron tank assembly. R12 and D5 are a network that absorbs the IGCT anode voltage spike while the switch is commutating from the On to the Off state. The simulation results of the circuit behavior for the variations R2, R4 and R12 values, respectively one at a time, will be presented below.

3. The effect of different R2 values (R4 = 10Ω, R12 = 10Ω)

(1) The different R2 values influence the peak voltage flat-top. This is shown in Figure 2. Increasing R2 values lead to increasing pulse flat top amplitude variation and width variation. With smaller R2 values the pulse flat top variation decreases as well as the flat top pulse width.

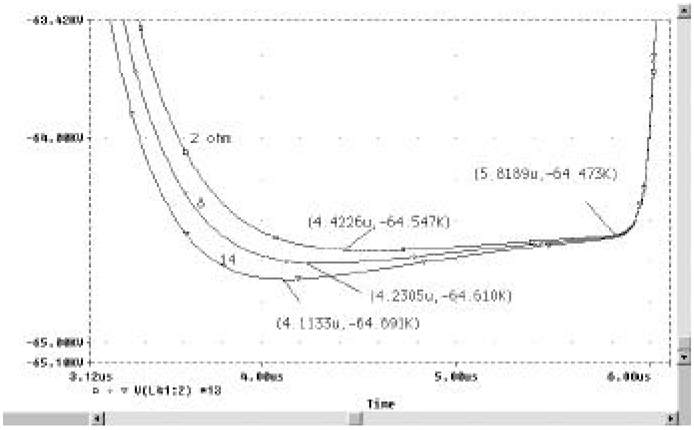

Figure 2: The effect of different R2 values on the peak voltage top flatness and width.

(2) With the same core bias current, the different R2 values influence the inverse voltage of peak voltage. When the R2 value is made smaller, the inverse voltage is lower. These variations are shown in Figure 3.

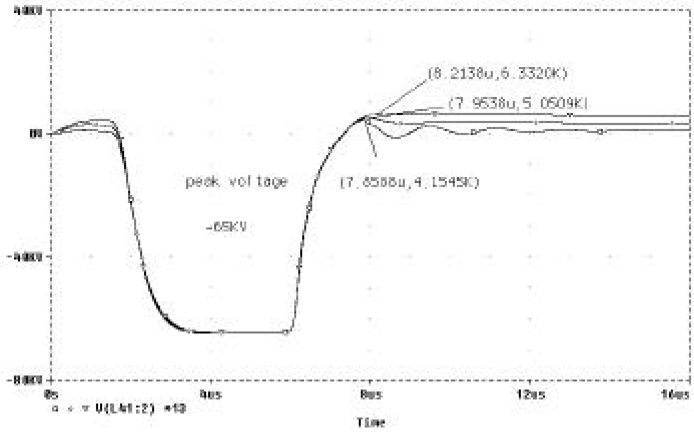

Figure 3: The effect of different R2 values on the peak inverse voltage

(3) The different R2 values also influence the spike of the IGCT anode voltage V(L7:2), the network voltage V(C29:2) and influence the clamp current I(R2). They are shown in Figure 4, Figure 5 and Figure 6. While the switch is going from On to Off, and the R2 values are small, the spike of V(L7:2),V(C29:2) is lower and the clamp current is higher.

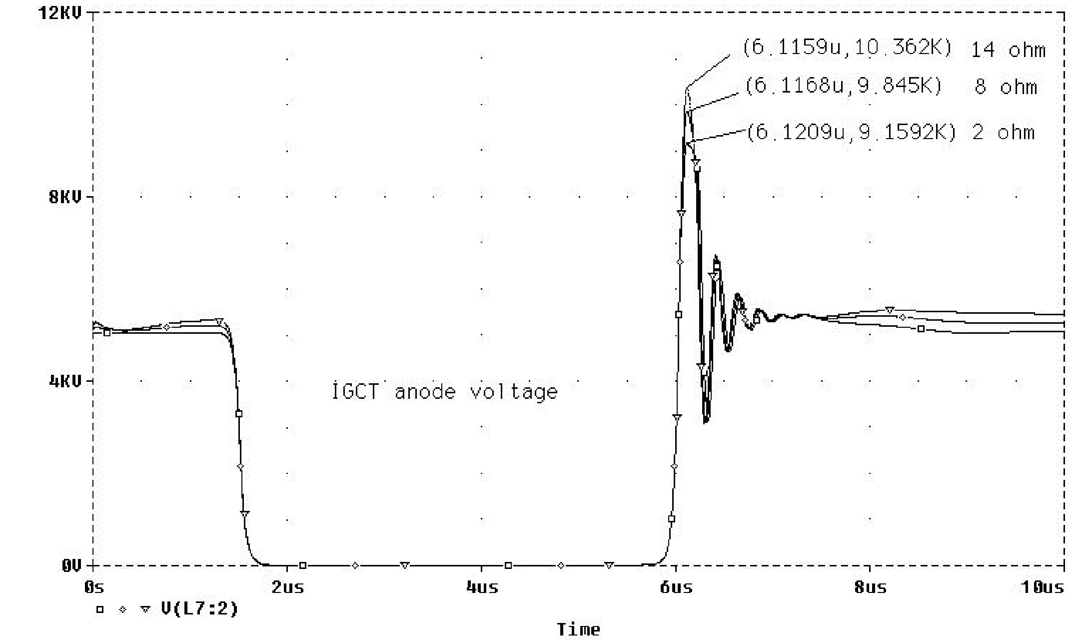

Figure 4: The effect of different R2 values on spike of the IGCT anode voltage V(L7:2)

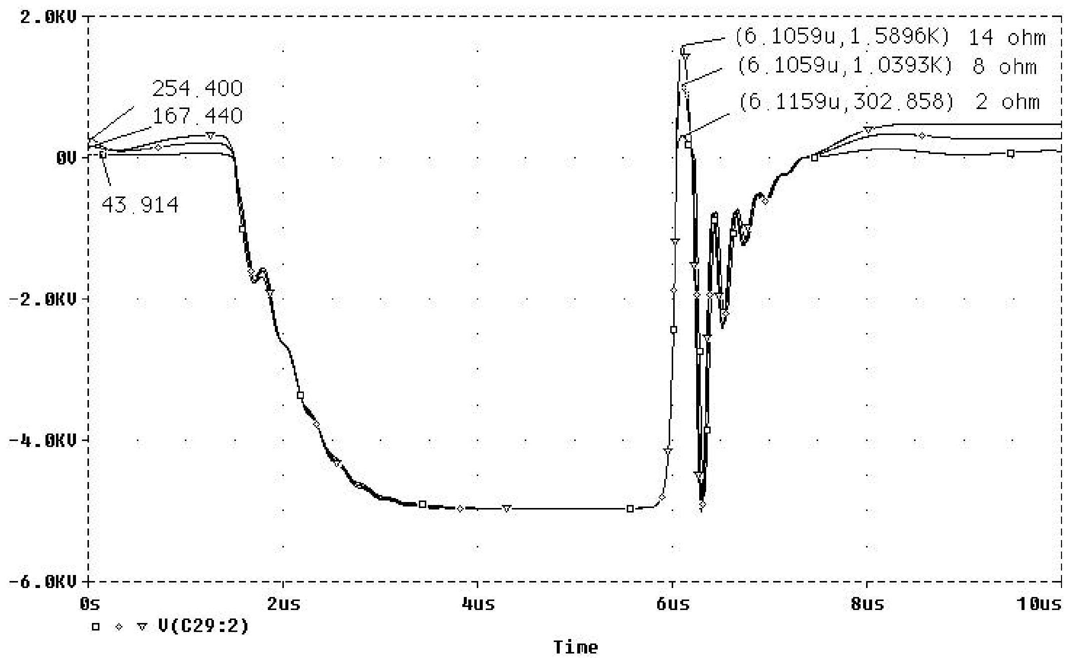

Figure 5: The effect of different R2 values on V(C29:2)

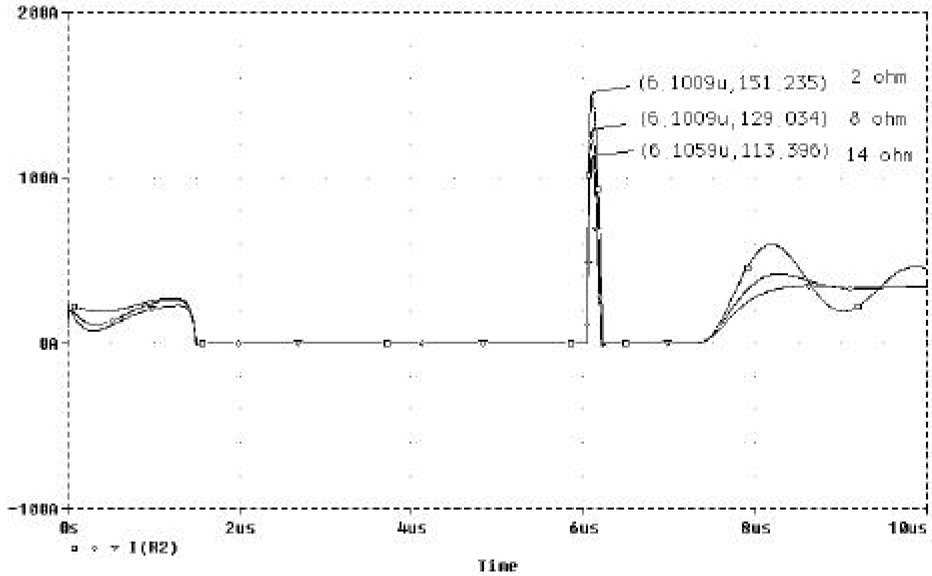

Figure 6: The effect of different R2 values on the clamp current I(R2)

(4) The different R2 values influence the start of network voltage V(C29:2), they are shown in Figure 4. The start of V(C29:2) is not close to zero voltage until R2 value is very small.

(5) The different R2 values influence the rise time of the IGCT current I(R8), I(C4) and I(C31) a little. When the R2 values are large, the rise time is faster. They are shown in Figure 7, Figure 8 and Figure 9.

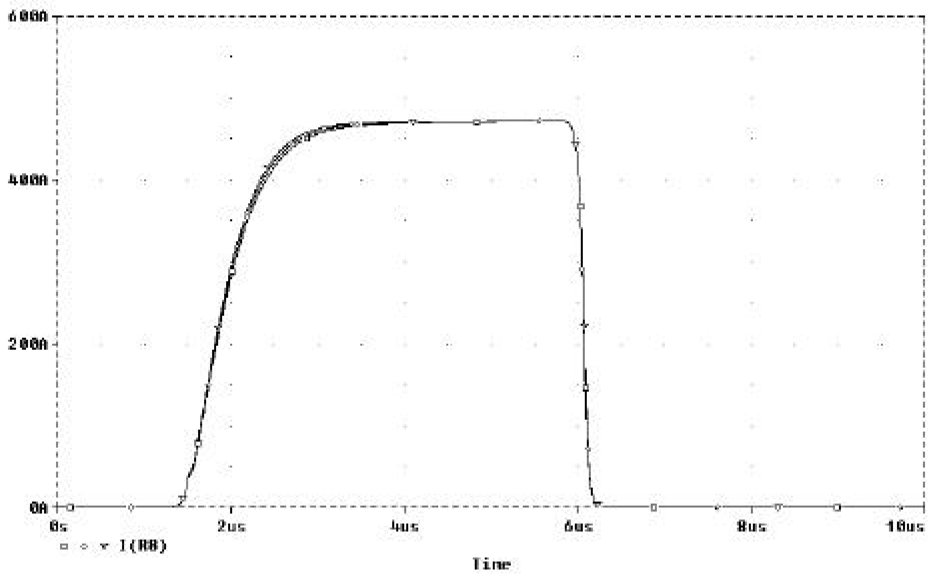

Figure 7: The effect of different R2 values on I(R8)

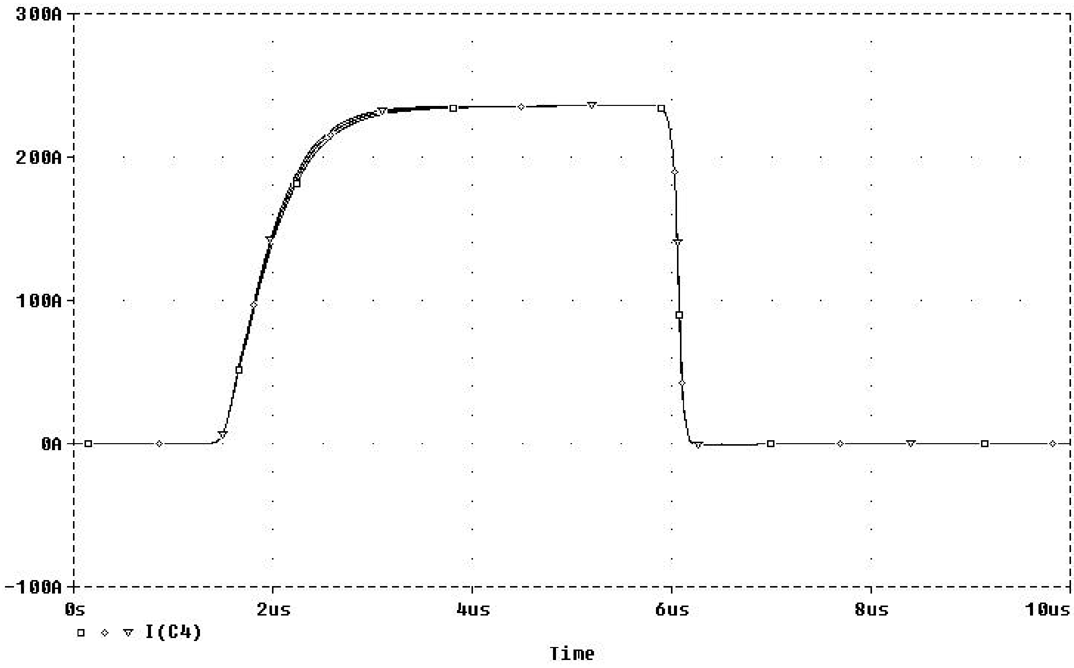

Figure 8: The effect of different R2 values on I(C4)

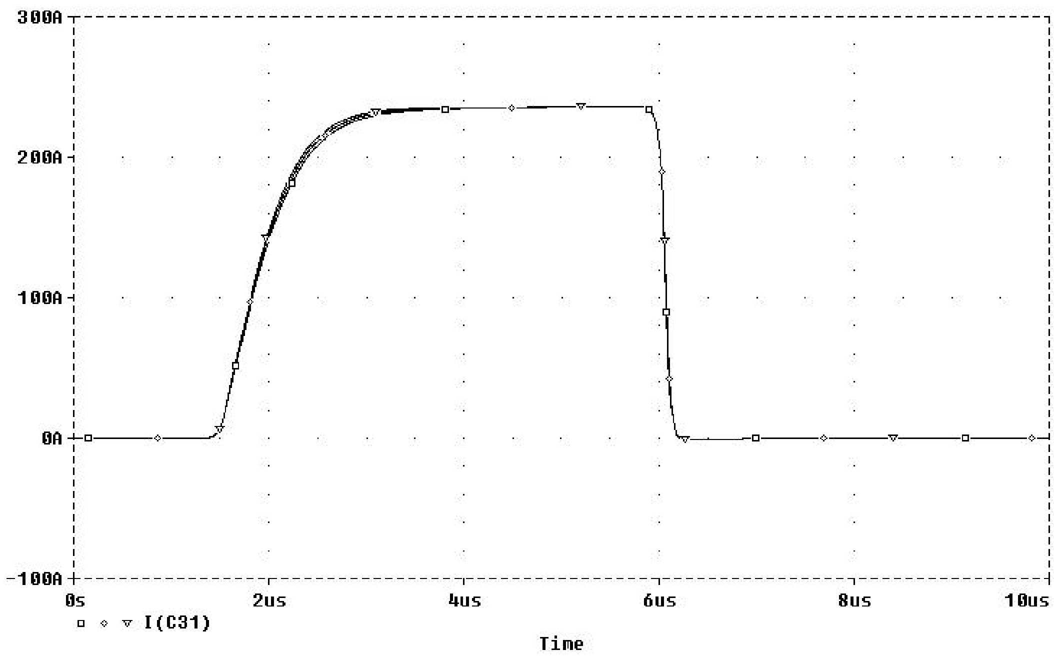

Figure 9: The effect of different R2 values on I(C31)

(6) The different R2 values influence the I(C30) and I(R4) a little. They are shown in Figure 10 and Figure 11.

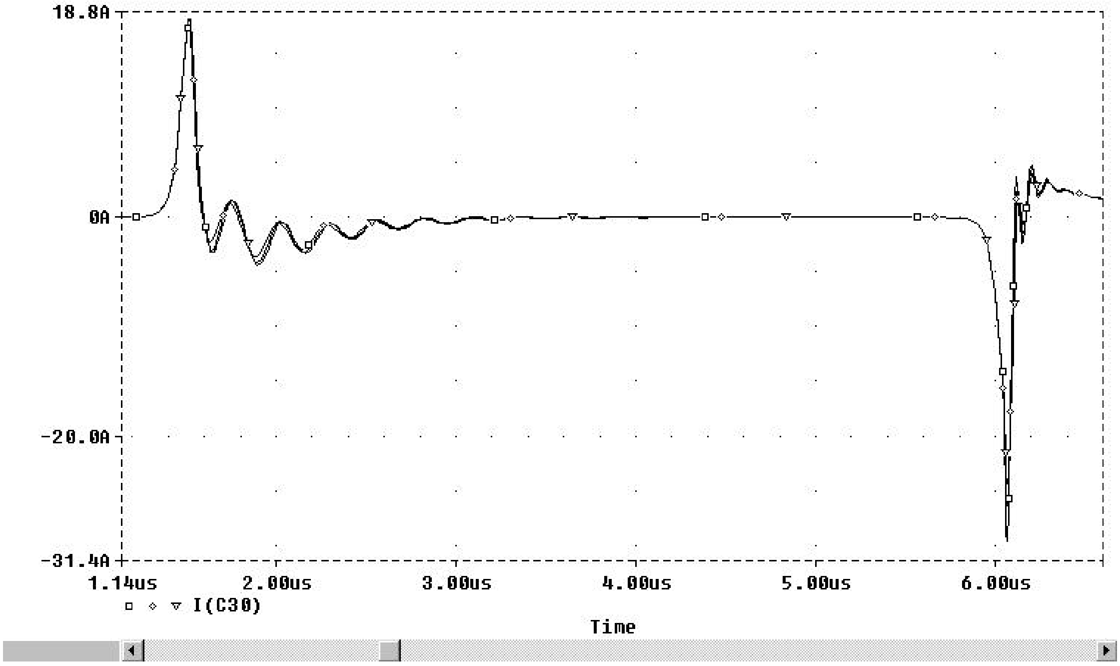

Figure 10: The effect of different R2 values on I(C30)

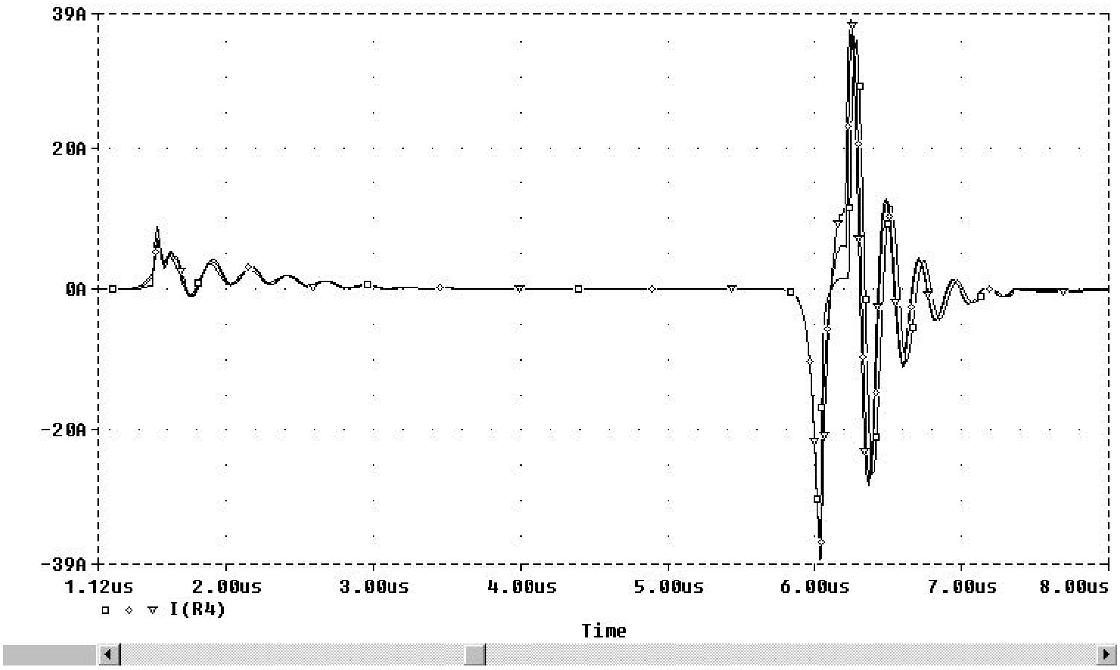

Figure 11: The effect of different R2 values on I(R4)

(7) The different R2 values do not influence the current I(D5). They are shown in Figure 12.

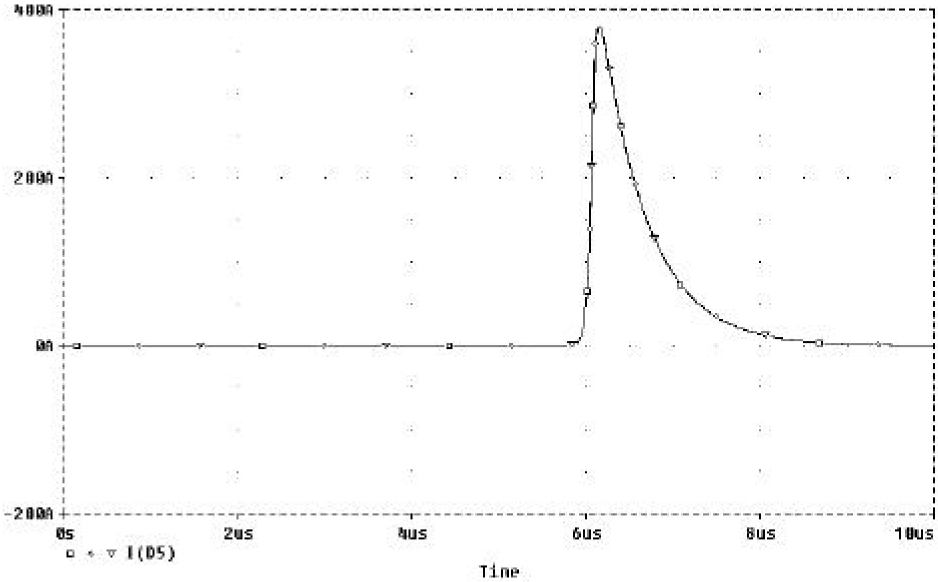

Figure 12: The effect of different R2 values on I(D5)

(8) Increasing the pulse width by the IGCT On/Off timing delay increases the total amount of pulse droop. This is shown in Figure 13 and Figure 14. The solution is to reduce the R2 value as is shown in Figure 15.

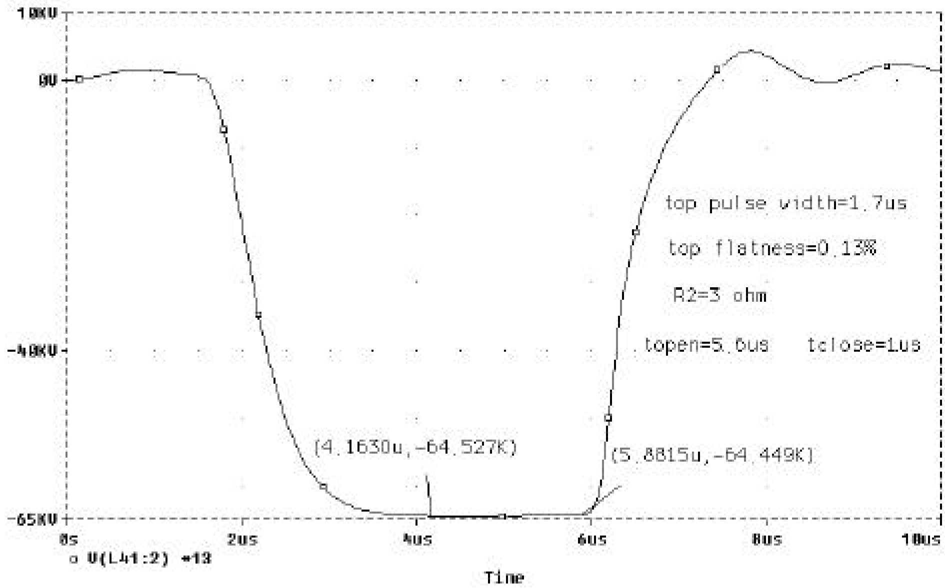

Figure 13: The peak voltage before increasing the pulse width by IGCT timing

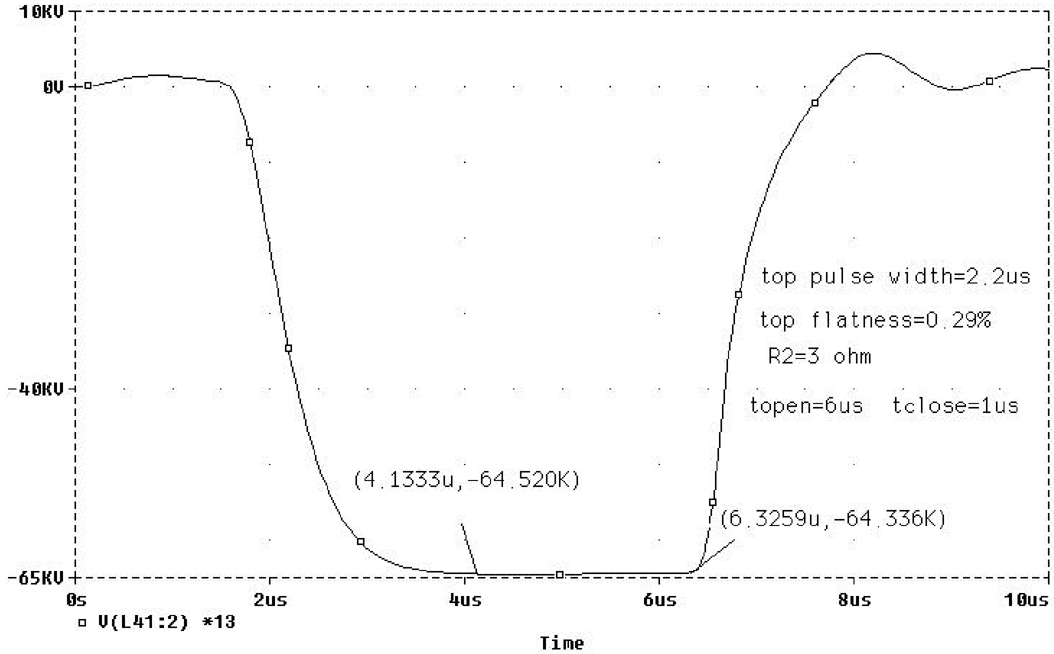

Figure 14: The peak voltage after increasing the pulse width by IGCT timing

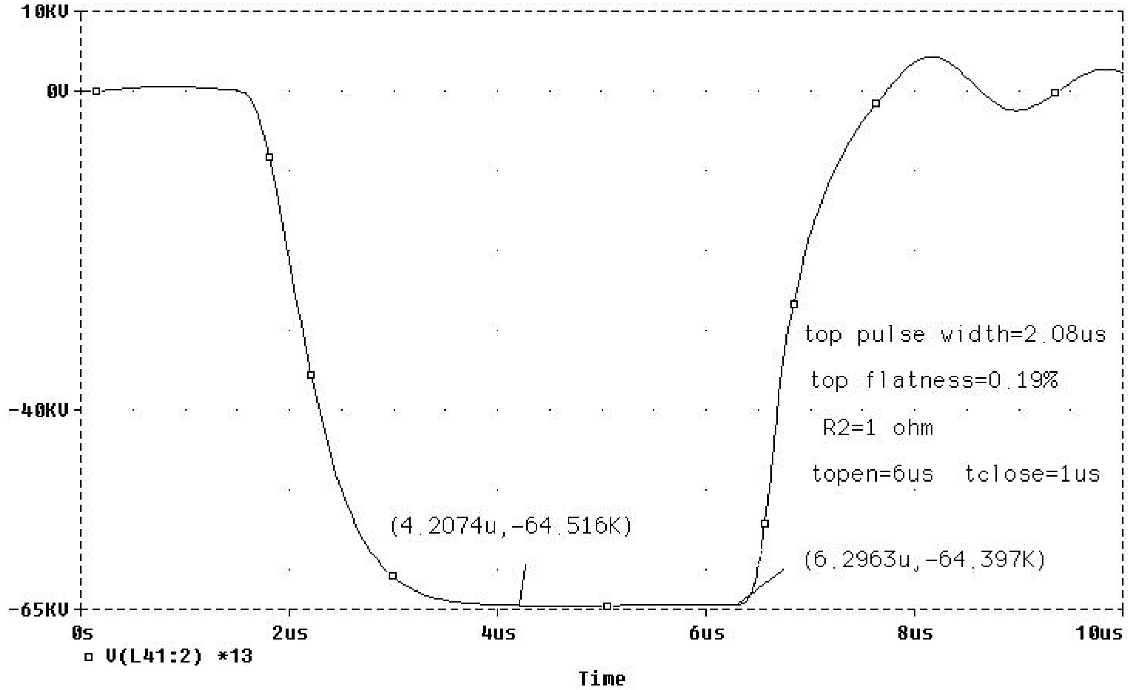

Figure 15: The peak voltage after reducing the R2 value to 1Ω

4. **The effect of different R4 values** (R2 = 3Ω, R12 = 10Ω)

(1) The different R4 values only influence the spike attenuation ratio of the IGCT anode voltage V(L7:2), V(C29:2), and I(R4) . They are shown in Figure 16, Figure 17 and Figure 18. When the R4 value is large, the attenuation is damped faster. The R4 value has a range of 5 to 15 Ω.

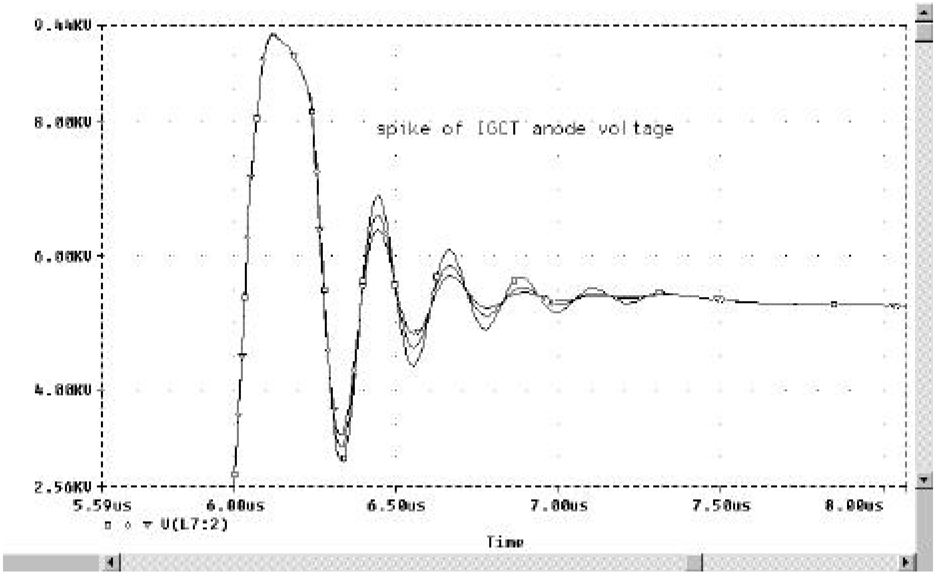

Figure 16: The effect of different R4 values on spike of the IGCT anode voltage V(L7:2)

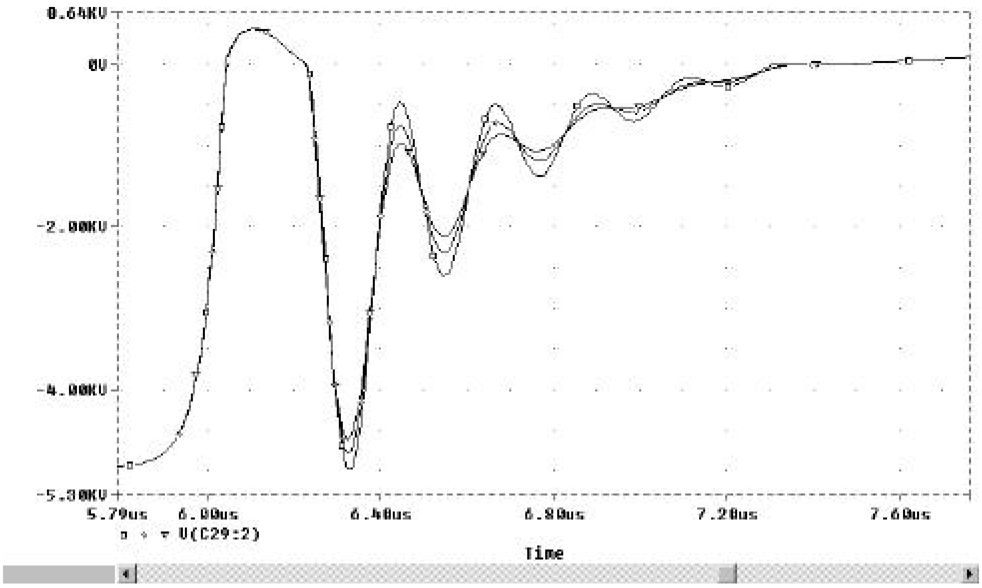

Figure 17: The effect of different R4 values on V(C29:2)

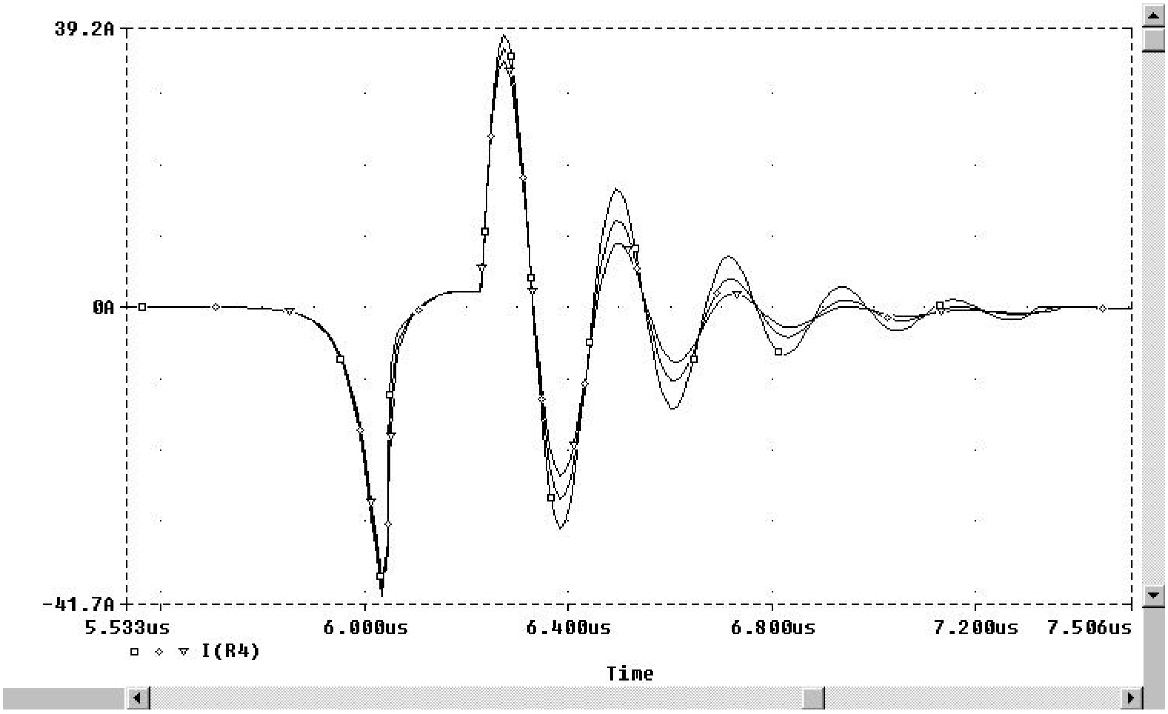

Figure 18: The effect of different R4 values on I(R4)

(2) The different R4 values influence the IC(30) a little. This is shown in Figure 19.

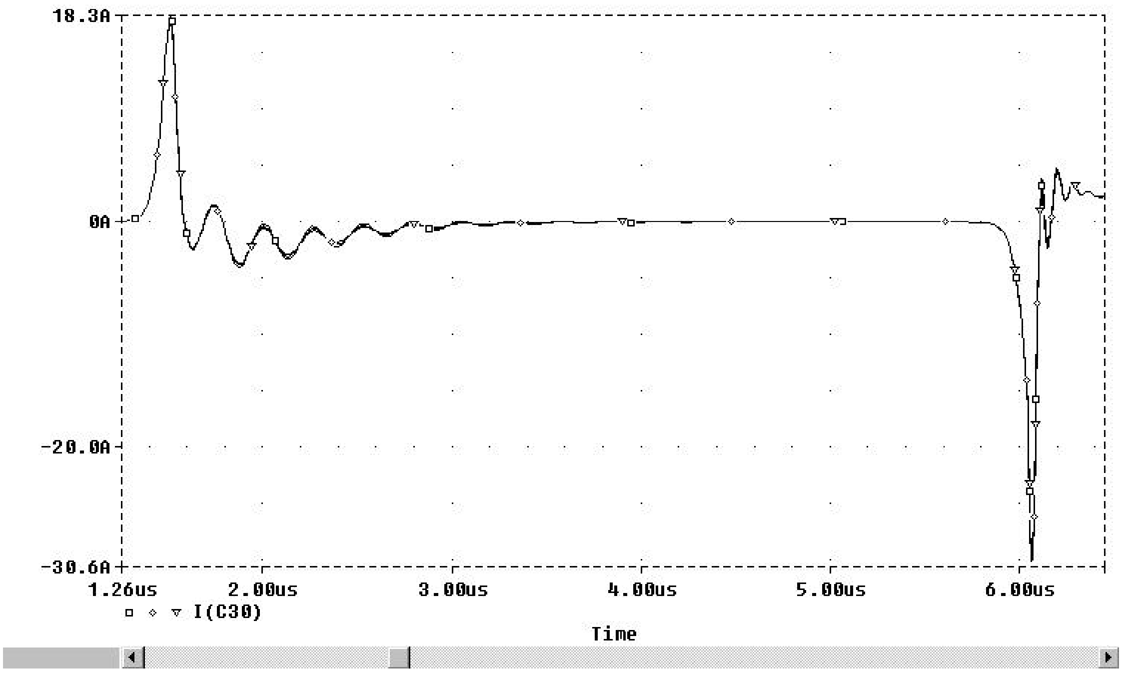

Figure 19: The effect of different R4 values on I(C30)

(3) The different R4 values do not influence the peak voltage V(L41:2), the clamp current I(R2), the IGCT current I(R8), I(D5), I(C4) and I(C31). These results shown in Figure 20, Figure 21, Figure 22, Figure 23, Figure 24 and Figure 25.

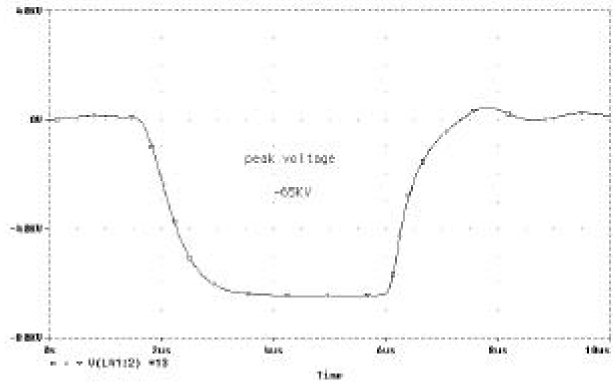

Figure 20: The effect of different R4 values on the peak voltage V(L41:2)

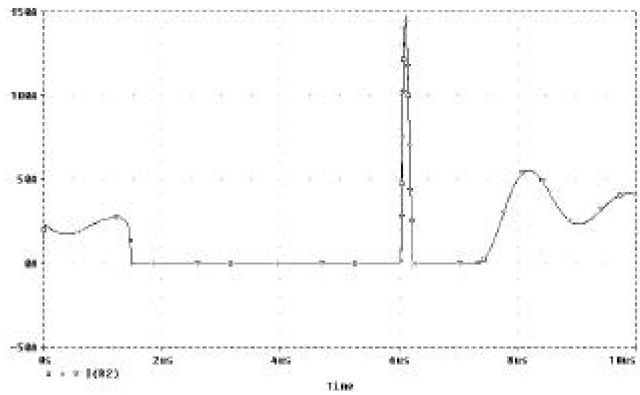

Figure 21: The effect of different R4 values on the clamp current I(R2)

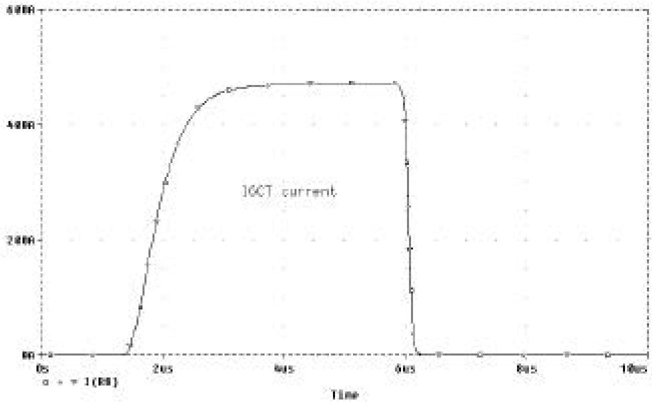

Figure 22: The effect of different R4 values on the IGCT current I(R8)

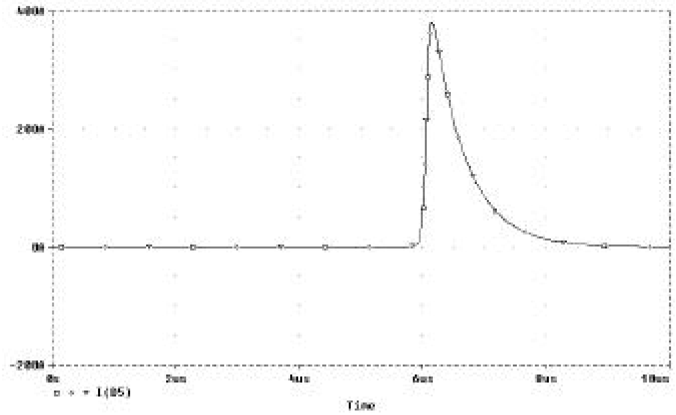

Figure 23: The effect of different R4 values on I(D5)

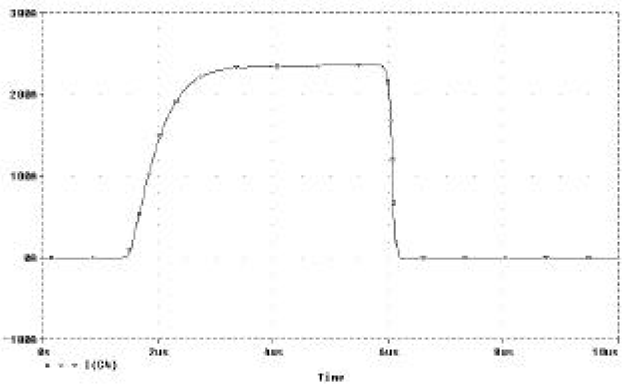

Figure 24: The effect of different R4 values on I(C4)

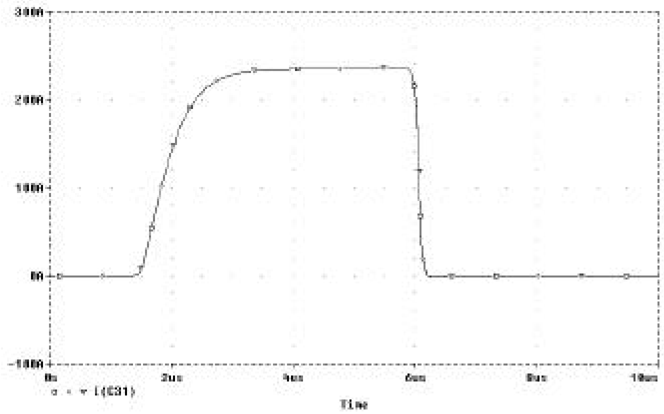

Figure 25: The effect of different R4 values on I(C31)

5. The effect of different R12 values (R2 = 3Ω, R4 = 10Ω)

(1) The different values of R12 influence the spike of the IGCT anode voltage V(L7:2), the clamp current I(R8), I(D5) and I(C30). When the R12 value is larger, the spikes of the IGCT anode voltage V(L7:2) and I(C30) are larger and the clamp currents I(R8), I(D5) are smaller. They are shown in Figure 26, Figure 27, Figure 28 and Figure 29, where the value range of R12 goes from 5 to 15 Ω.

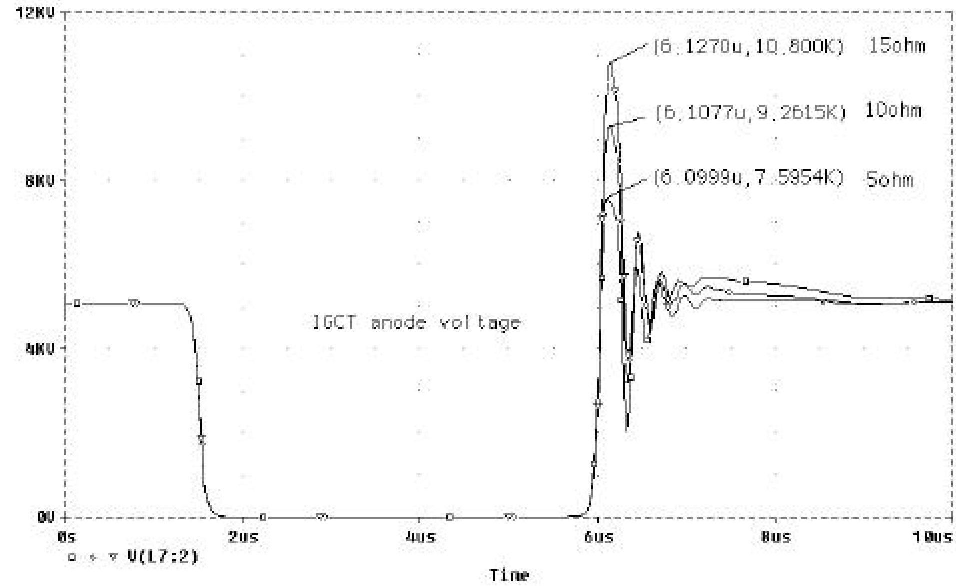

Figure 26: The effect of different R12 on spike of the IGCT anode voltage V(L7)

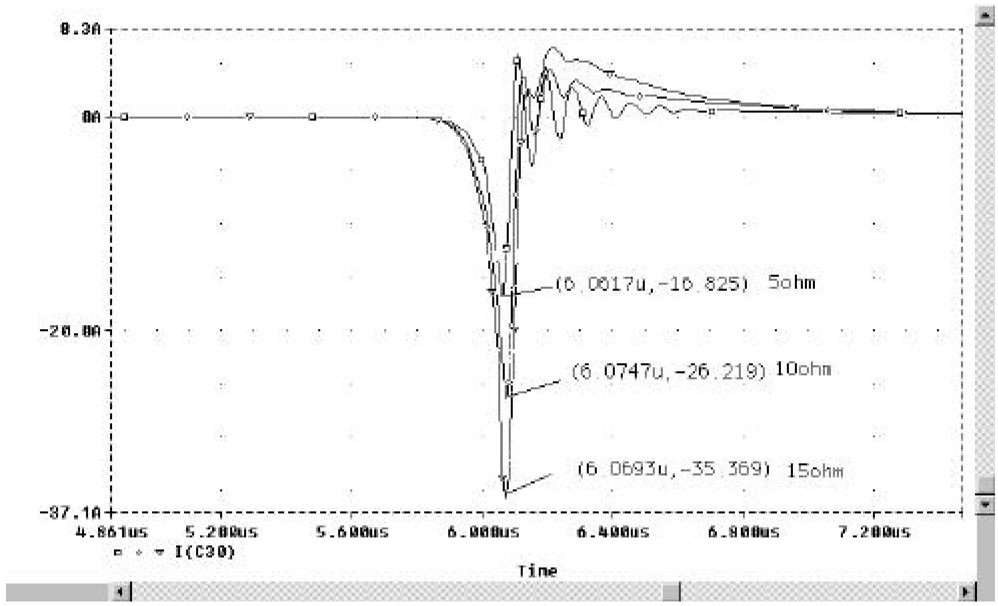

Figure 27: The effect of the different R12 values on I(C30)

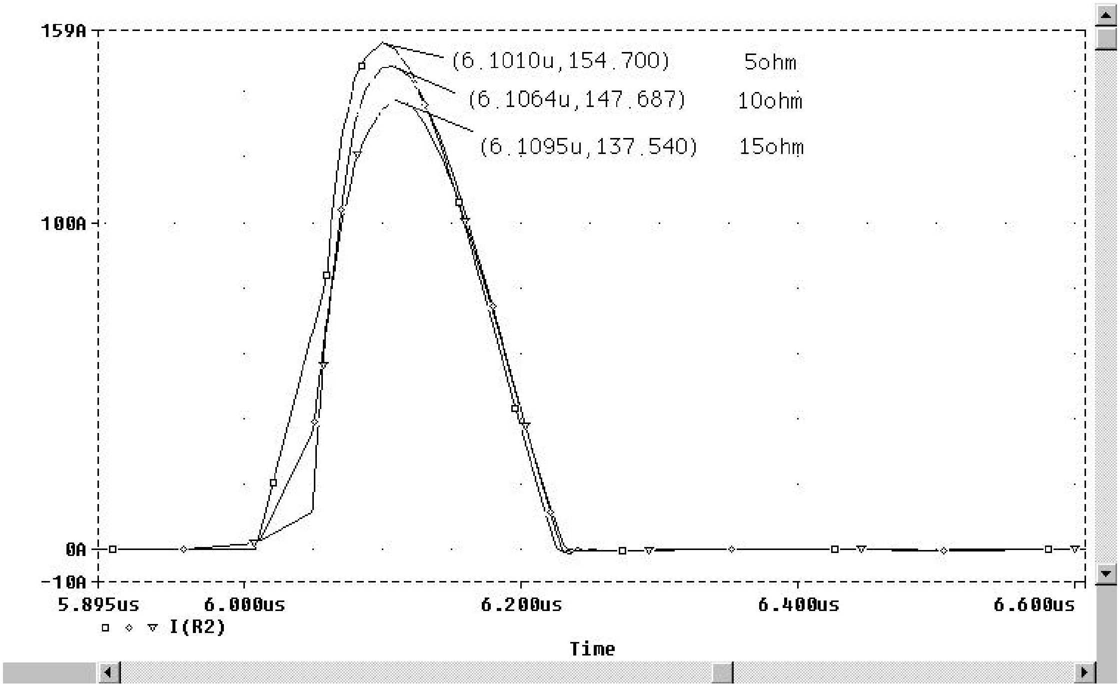

Figure 28: The effect of different R12 values on the clamp current I(R2)

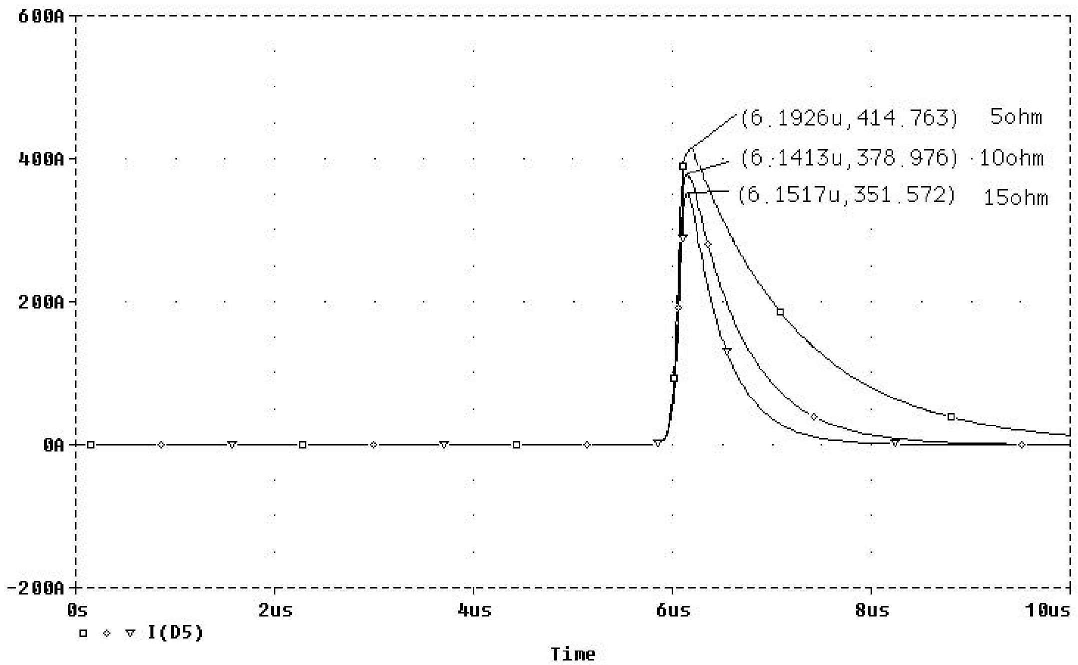

Figure 29: The effect of different R12 values on I(D5)

(2) The different R12 values do not influence the peak voltage V(L41:2), V(C29:2), the IGCT current I(R8), I(R4), and I(C31). They are shown in Figure 30, Figure 31, Figure 32, Figure 33 and Figure 34.

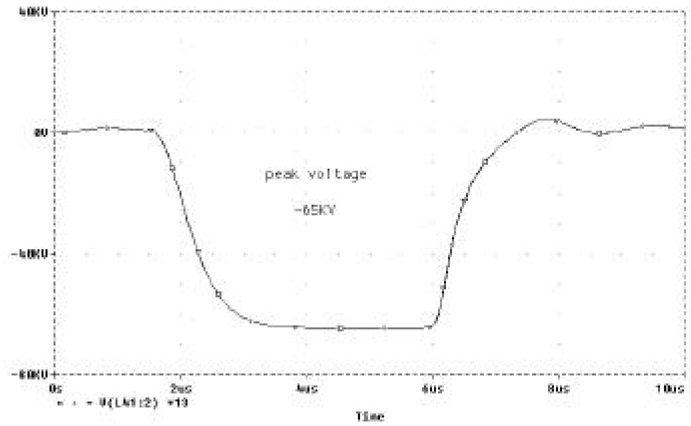

Figure 30: The effect of different R12 values on the peak voltage V(L41:2)

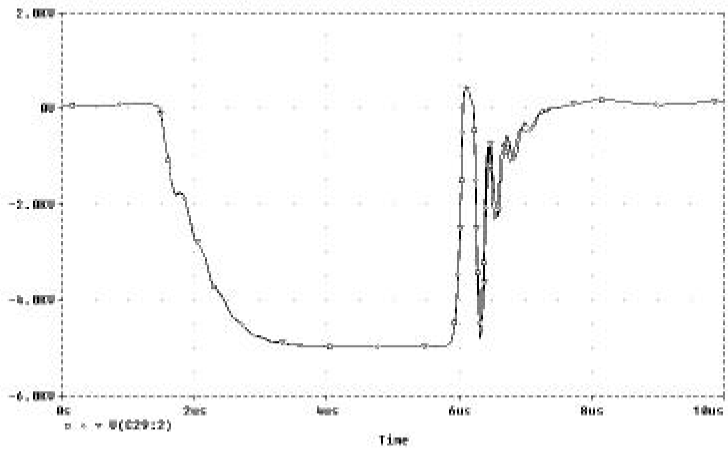

Figure 31: The effect of different R12 values on V(C29:2)

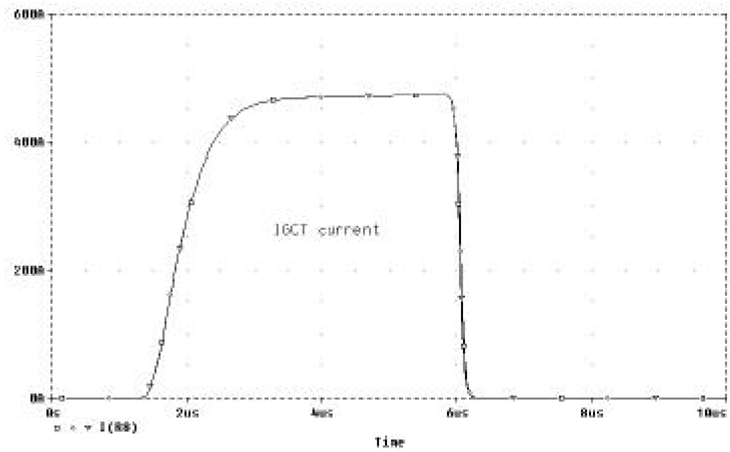

Figure 32: The effect of different R12 values on the IGCT current I(R8)

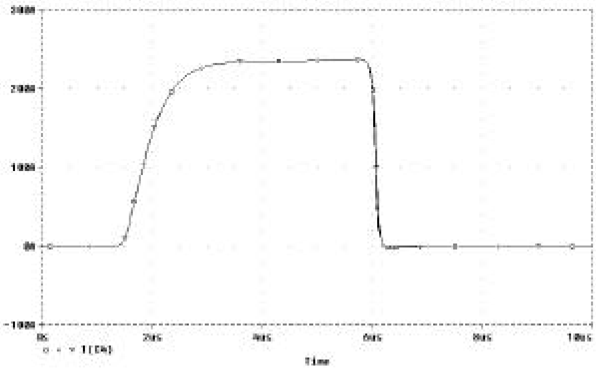

Figure 33: The effect of different R12 values on I(C4)

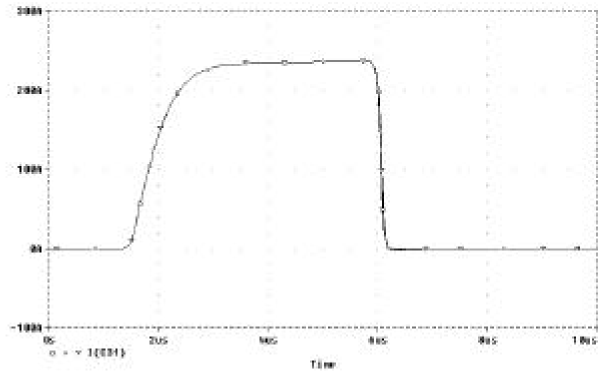

Figure 34: The effect of different R12 values on I(C31)

6. Conclusions

According to the simulation results, we choose the R2, R4 and R12 values that give the best klystron high-voltage pulse shape and that has the smallest droop over the desired pulse width. These values are shown in Table 1.

Table 1: Resistor values

R2 R4	3 Ω 10 Ω
R12	10 Ω

Using these values for R2, R4 and R12, we can achieve a satisfactory peak voltage pulse shape, as shown in Figure 35 and Table 2. These values will be used for the initial testing of the klystron pulser circuit, but they may have to be optimized for practical components values to obtain the desired results.

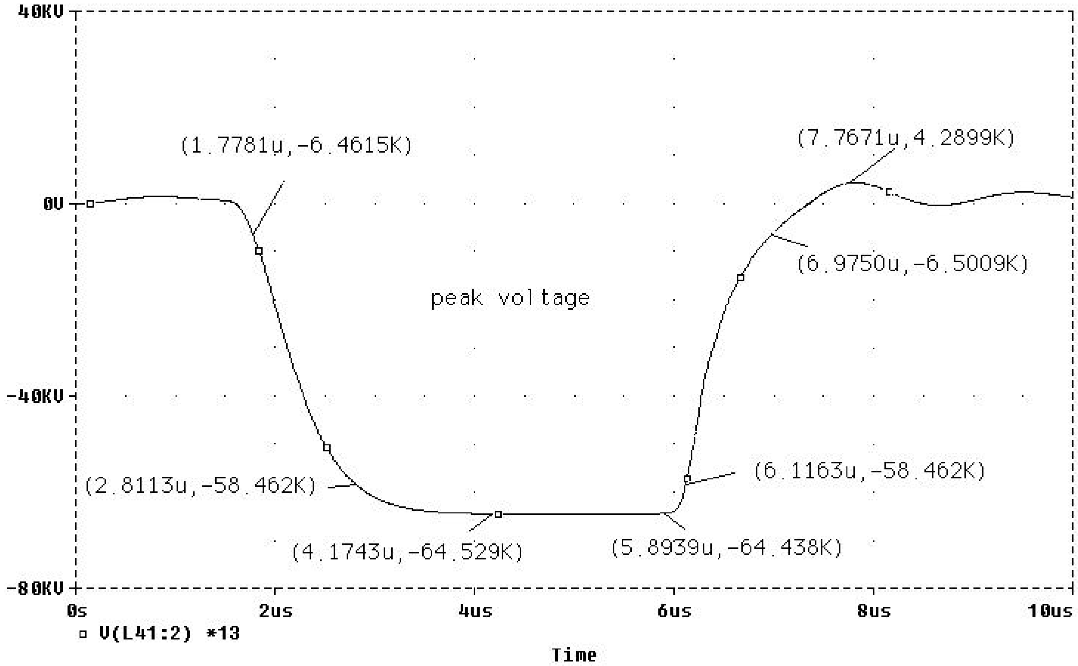

Figure 35: The klystron voltage pulse, achieved with chosen resistor values

Table 2: The peak voltage parameters that are satisfied by the resistor chosen are given below.

Peak voltage	-65kV
Top-pulse width	1.72µs
Rise time	1.03µs
Fall time	0.86µs
Top-flat	0.14%