BEHAVIOUR OF HIGH CURRENT SWITCH FOR LMJ PROJECT

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Abstract

The pulsed power system for the Megajoule laser (LMJ) facility [1] will use high current, high charge gas switches. One of the candidates is the switch developed by IHCE (Institute of High Current Electronics) and ITHPP which is described in [2]. Some complementary experiments have been conducted at CEA to know some limits of this device. The first one was to use the switch in short-circuit in order to increase the peak current and the charges transferred by the switch. The current has been increased to 380 kA and the total charge across the switch reached 420 C. The second experiment is dealing with the sensitivity of the gas purge. The goal was to know the behaviour of this switch when the gas is not replaced after the shot. In any cases the switch resists to this news stresses.

I. INTRODUCTION

HCEI and ITHPP have developed for CEA (LMJ power conditioning) two spark gap switches (pre-ionization and main switch) where the spark is initiated in a three electrode configuration, it accelerates due to electro-dynamical force and moves along the two extended electrodes. The diameter of the extended electrodes allows controlling the spark velocity and hence the erosion of the electrodes providing the required 20000 shots life time for LMJ.

The experiments conducted on the main switch are a complement to the qualification tests performed in 2005. The qualification was essentially focused on the nominal operating point i.e. 24 kV, 250 kA, 70 C, 20000 shots without any prefire or misfire.

These tests have been done on the qualified prototype, this means, all the parts of this switch have already seen at least 20000 nominal shots.

II. SHORT-CIRCUIT BEHAVIOUR

During the life of LMJ many short-circuits on flash lamps will occur. The current on the components of one mesh rise to twice the nominal current, in our case this means ~ 50 kA. So the behaviour of the switch with short-circuits and the knowledge of the safety margin will give some ideas of the robustness. Some of the others components: capacitors, cables are already designed to support this current. The inductors used in these tests came from older experiments and were rated to only 35 kA.

The equivalent circuit for this configuration is given in the Fig. 1. The 2900 µF capacitor and 4.1 µH inductor represent the ten meshes components in parallel. On the left of the Fig.1 is represented the preionization circuit witch is common for ten meshes.

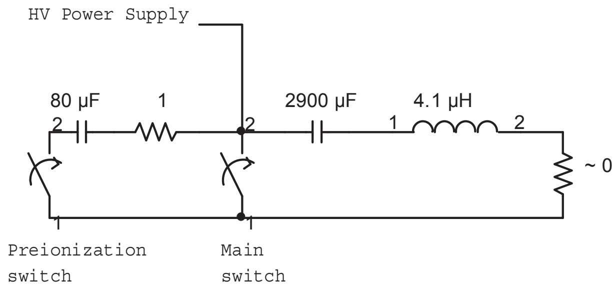

Figure 1. Equivalent circuit for the short-circuit tests

The charge voltage was increased from 8kV up to 16 kV. The current was measured with Pearson coils.

The Fig.2 shows the current across the switch in the nominal configuration and in the short-circuit case.

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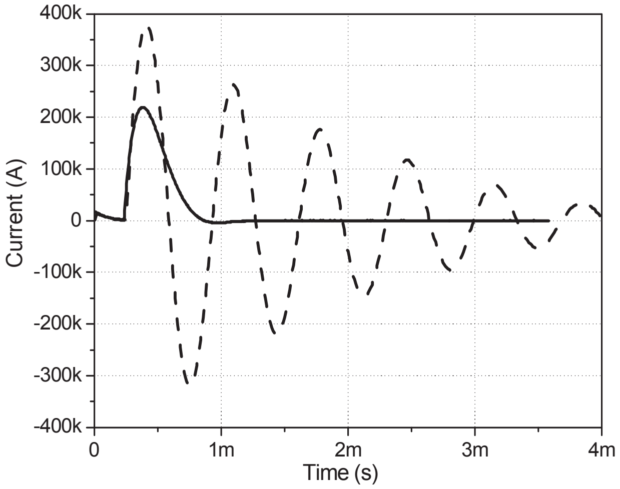

Figure 2. Current through the switch (solid line: nominal current at 24 kV, dash line: short-circuit current for 16 kV charging voltage.

With short-circuit at lower charging voltage the peak current is 50% larger than the nominal 250 kA. The total charge across the switch (Fig 3.) reached 420 C. This quantity represents six times the nominal charge. If we consider that momentum induced by magnetic field on electrodes varies like $\int i^2\, dt$, this test shows a large safety margin on the mechanical robustness.

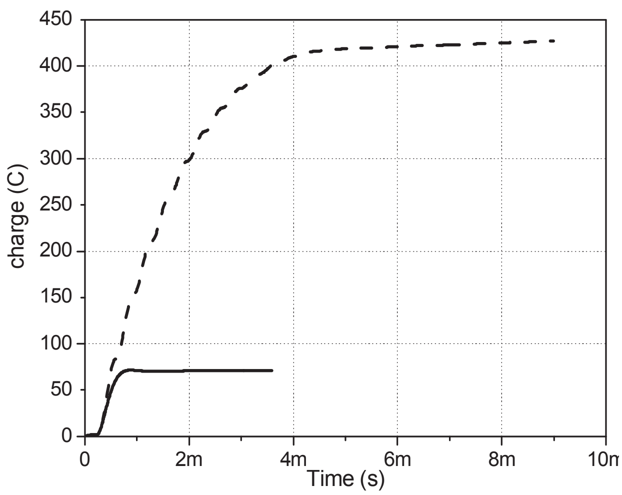

Figure 3. Charges through the switch (solid line: nominal operation, dash line: short-circuit case at 16 kV charging voltage.

After these series of shots the short-circuits have been removed. Few shots done on resistances at the nominal point didn't show any degradation of the performance of the switch. The delay and jitter haven't been affected.

III. SIMULATION OF PROBLEM ON THE PURGE CIRCUIT

For reliable operation the switch needs to be purge after each shot in order to evacuate debris and renew the dry air to maintain the same operating point. The LMJ will use near one thousand switches (pre-ionization and main). From a reliability point of view: Do we need to control this purge with expensive flowmeters ?, Does the switch can be destroyed if shots are performing without a purge?

To answer, a series of shots have been done on resistive loads representative of the flash lamps.

We have measured with a particular attention the delay between the trigger pulse and the beginning of the current.

The Fig 4. shows the evolution of the delay without the purge. The switch starts with larger and larger delay. The delay increases from 1µs to ten times the nominal value after few shots without purge. After the seventh shot a nominal purge was done, immediately the delay came back to the nominal 1µs.

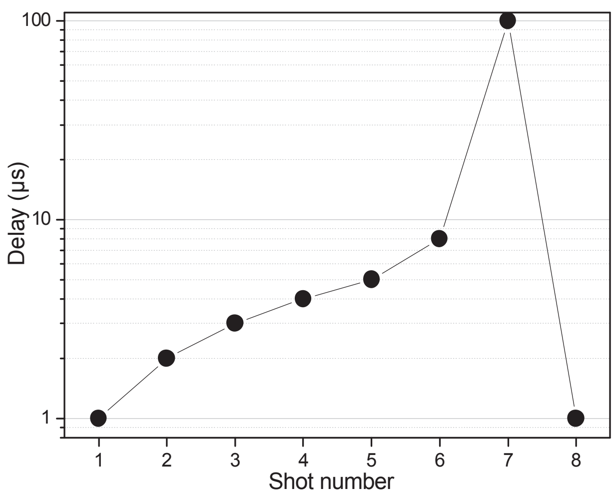

Figure 4. Evolution of the delay between the trigger and the rise of the current on the main switch. The switch wasn't purged after shot 1 to 6. The purge was restarted after the seventh shot.

On LMJ, it was already decided to record the current in each mesh with 12 bits and at least 1MHz sampling rate. So we can consider that the automatic analysis of the delays on the current can help us to detect problems on purge system. By such way, if the design of this purge system is properly designed, we thought we don't need to use hundreds of flowmeters for ensuring reliability.

IV. CONCLUSION

Theses tests confirm our trust in this switching solution for LMJ or high charge, single shots applications. This solution is clearly robust. Defaults modes on load or servitude do not affect the performances. For other application, the current and charge can be increased perhaps with limited life time but allows to use the existing switches without redesigning and rebuilting it.

V. REFERENCES

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[2] B.M. Kovalchuk, A.A KIM "Three electrodes spark gaps with electrodynamical acceleration of the discharge channel" in proc of 15 th IEEE Pulsed Power Conf., Monteray, 2005.