High voltage, high current thyristors matrix

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Abstract

INTRODUCTION

The Electrical engineering and Copper vapor laser Technology Laboratory (LETC) of the Commissariat à l'Energie Atomique (CEA), in Pierrelatte, carries out the study and development of high power high voltage electric supplies for the uranium enrichment process by laser SILVA. One of the specialties of this laboratory consists in replacing gas-tubes (thyratrons, ignitrons and tetrodes) by solid-state small standard components connected in matrix, on printed circuit boards. This new converter topology has been presented in a key note paper at PCIM'99 [1].

Nowadays, a high reliability high voltage fast switches, using MOSFETs matrix, reaches the industrial level [2][3]. This supply is a high voltage (30kV), high current (2kA), high frequency (up to 20kHz) pulsed switch, design to run in pulsed laser supplied, in water treatment by high electrical field and in plasma oven.

The aim of the paper is to present high voltage, very high current (10kA) power switch using small standard thyristors in a matrix topology.

STRUCTURE OF THE PRODUCT

The matrix consists in associations of small standard thyristors in TO220 case on printed circuit board. Each board is composed of 150 thyristors, 15 associations in series of 10 components in parallel, so as to make a 10kV 10kA switch. All the components are driven simultaneously.

Current consideration

MOSFETs and IGBTs have a silicon surface including thousands of cells in parallel. The conduction of the component starts on the entire surface. There is no dI/dt limitation as in a thyristor. On a thyristor surface, the gate is located on a small part. At turn on, conduction's plasma is created near the gate and diffuses slowly on all the surface. These is a critical current rate specified by supplier not to burn the component by localization of current on a small part of the component's

surface. The dI/dt depends of gate distribution on the surface. For high dI/dt the gate has to be interdigitated.

Thyristors switch is designed with small thyristors in parallel. The dI/dt specified for a small thyristor has the same level as a high current one. Due to the parallel design, global dI/dt of thyristors in parallel is the sum of individual dI/dt. Furthermore this specified dI/dt is given for a low gate current.

With an initial high level of gate current it is possible to reach higher dI/dt. A small thyristor, 12A nominal current, is 100A/µs specified. In fact, with a 2A initial gate current, we measure a dI/dt of 1000A/µs. With 10 thyristors in parallel the dI/dt calculated with supplier specifications is 1kA/µs but the real limitation is higher than 10kA/µs with high initial gate current.

Voltage consideration

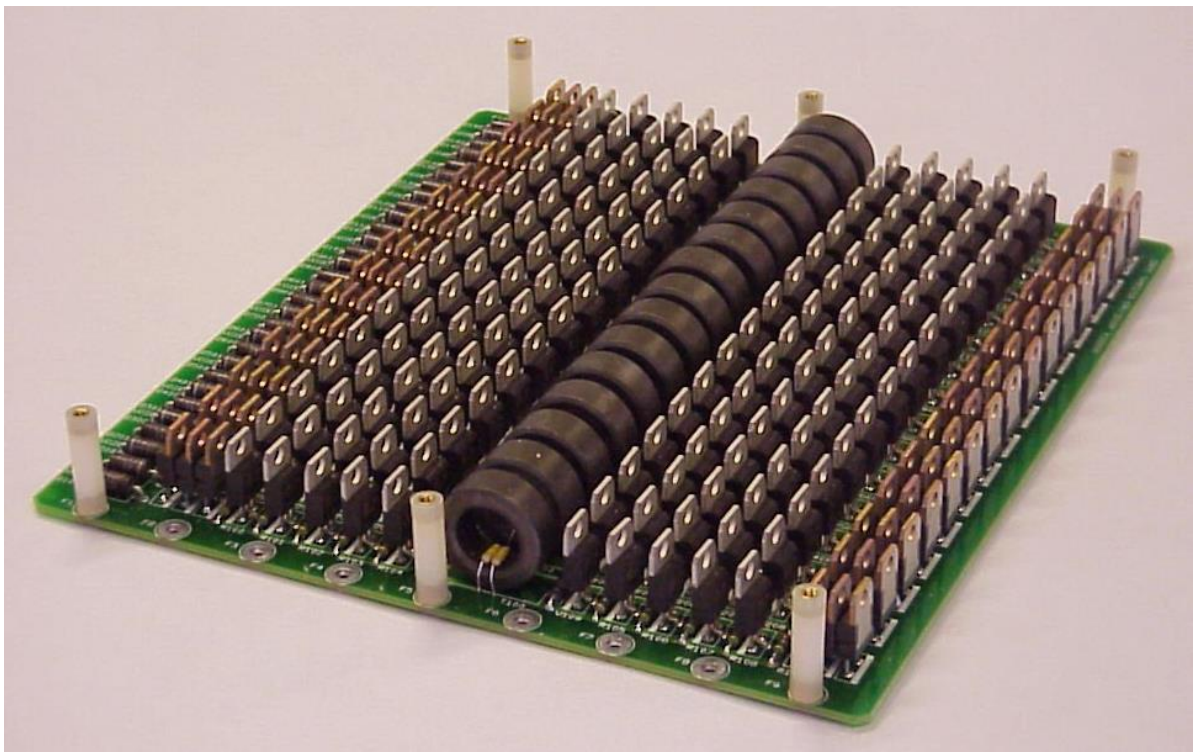
In order to obtain high voltage switches, components are serial connected [4] [5]. In our case, there is no additional voltage balancement system. The technique consists to maintain each stage of components in its voltage safety area. We use over-voltage protection like transil on each stage of thyristors.

Drive technique

In order to assure very good repartitions of the current and the voltage during the turning on of the matrix, components have to be driven simultaneously. We use pulse transformers on each stage of the serial association. This technique of control provides galvanic insulation between control signals and power, and synchronous drive by serial connection of the primaries of the transformers.

Photograph

The following photograph presents the thyristors matrix, industrialized by CENTRALP Enertronic.



20kV, 10kA Thyristors board switch.

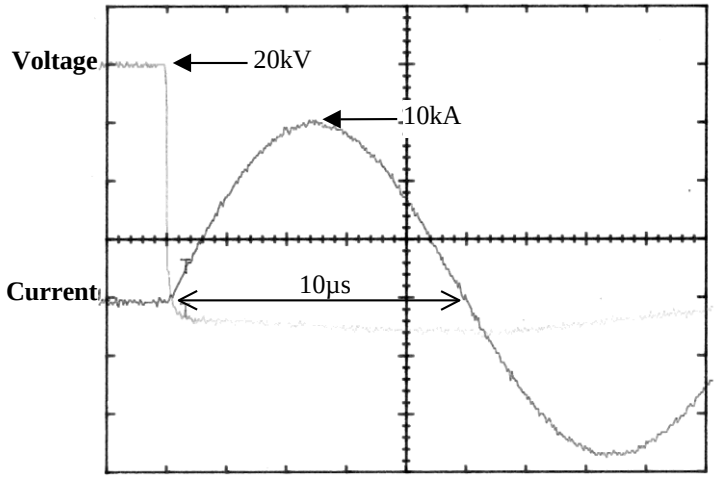
PRODUCT APPLICATION

The application of such switch is typically the crowbar. This parallel protection system has to run under very high voltage and must be able to short-circuit high current. Moreover, it has to turn ON very fast and to allow high dI/dt. This function is usually looked after by triggered spark gaps or ignitrons with reliability and aging problems or by slow high voltage relays (mechanical systems).

The thyristors matrix regroups advantages of these different systems : Performances low cost and industrial state.

PERFORMANCES

With a switch of two boards in series, we generate a 10kA 20kV pulse for a 10µs duration. The following curves present the voltage and the current during the turning-ON of the couple of thyristors matrix.



- Voltage fall time : 20kV in 20ns
  ⇔ **dV/dt = 1MV/µs**

- Current rate
  ⇔ **dI/dt = 12kA/µs**

Nowadays, we are building a 100kV 10kA crowbar, consisting of 12 thyristors matrix in series. The final product would be finish and test during January 2000. It will not exceed 90cm high. This product will be presented in the final paper.

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