LIGHT TRIGGERED THYRISTOR CROWBAR FOR KLYSTRON PROTECTION APPLICATION

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Abstract

High power klystrons have to be protected in case of arcing or other failures. In most applications this is achieved by fast closing switches operating in parallel to the klystron path. These switches are known as crowbars. Most commonly used crowbar switches are sparkgaps, thyratrons and ignitrons. Recent progress in the development of high power semiconductors introduces the possibility to apply semiconductor closing switches as crowbars. The most promising approach is the application of the Light Triggered Thyristor (LTT). This especially is interesting for high power high voltage dc installations, like hvdc klystron power supplies with appropriate protection requirements. This paper describes a solution using series connected LTTs as a closing crowbar switch. Static and dynamic behaviour of the thyristors are introduced. The special requirements regarding the crowbar applications are pointed out. Results of a first prototype are presented to replace sparkgaps within an existing installation, where very high charge transfer capability has to be achieved.

INTRODUCTION

Despite recent attempts to introduce opening switches for klystron protection applications the closing switch approach is still the most commonly used. This is effected by the possibility to dump all the stored energy of the main circuit elements. This regards to lumped elements and parasitic elements respectively. Several high voltage switching technologies have been in use for years. Significant progress in high power semiconductor technology opens up new possibilities. The development of the Light Triggered Thyristor looks attractive for high voltage applications. These thyristors were developed for HVDC links in the power distribution industry. Improvements in their dynamic switching parameters made them suitable for high dI/dt requirements. Furthermore the optical gate control allows convenient series connections limited only by the quality of the applied optical fibre and its appropriate length.

LTT-CHARACTERISTICS

Light Triggered Thyristors are characterized as their electrically triggered counterparts. Except the triggering is achieved by a laser pulse applied to the integrated amplifying gate structure. The main electric parameters of LTTs for phase control applications are attractive in high voltage and high surge current capability. But they suffer from poor dI/dt values, which is required in crowbar applications. The break-through was made with the dedicated modification of the resistive area within the optical gate structure of the thyristor pellet [1]. This leads to application specific thyristors with hard switching behaviour. The result is a optimized thyristor combined with appropriate operating conditions. This method can be summarized as follows:

- Reduced voltage level to about half of the nominal value during dc operation, which results in significant lower off-state currents and minimizes the probability of charge carrier generation initiated by cosmic radiation.
- Reduced operating temperature leads to further reduction of the off-state current, which simplifies voltage balancing requirements in series connected thyristor assemblies.
- Modified gate resistor value gives the possibility of higher dI/dt and pulse currents.
- Increased optical power of the applied gate pulse leads to further improvement of pulse operation.

The general dependencies of the off-state current on voltage and temperature are given by the manufacturer [2]. The reduction of the off-state current for dc operation combined with the modification of the optical gate and reduced operating temperature are the most important steps toward the application of LTTs for klystron protection. The significant thyristor parameters are pointed out in the following table.

Table 1**:** Typical parameters of a LTT compared to its hard switching version.

	T1503N 75T (STANDARD)	**T1503NH 75T S02 (HARD SWITCH)**
V_{DD},V_{DR} [V]	7500	7500
I_{TAV} [A]	1760	1760
I_{TSM} [kA]	40	40
I_D [mA]	500 @7500V/120^{o}C	**0.8 @4000V/50^{o}C**
di/dt $_{max}$ [A/µs]	1000	**5000**
$I_{peak\text{-}pulse}$ [A]	not specified	**5000**
$P_{optical\ gate}$ [mW]	40 @ 10µs	**100 @ 10µs**
t_{don} [µs]	5	3…4

Measured thyristors show I_D-values in the range between 100µA and 400µA instead of the promised 800µA. This gives an additional margin regarding static voltage balancing requirements. The improved dI/dt capability is attained by the appropriate integrated gate resistor value.

SPECIAL REQUIREMENTS FOR CROWBAR APPLICATIONS

Special requirements for crowbar switches used in klystron protection circuits can be summerized as follows.

- Continuous high voltage dc operation without self breakdown.
- High pulsed currents and high dI/dt during the starting phase of the capacitor discharge.
- High charge transfer capability due to large smoothing capacitors and the follow-through current of the power supply.
- Wide range of dc operating voltages to ensure protection during the power-on procedure of the power supply.
- Low trigger delay.

LTT CROWBAR PROTOTYPE

A first prototype has been build consisting of two LTT stacks with 7 thyristors each (figure 2). The thyristors are the special types T1503NH75TS02. The mechanical assembly of two stacks vertically within a movable construction has been chosen for simple replacement inside the high voltage room. The electronic unit with the laser diodes is located inside the bottom frame (figure 1).

Figure 1: LTT crowbar assembly consisting of two stacks mounted vertically.

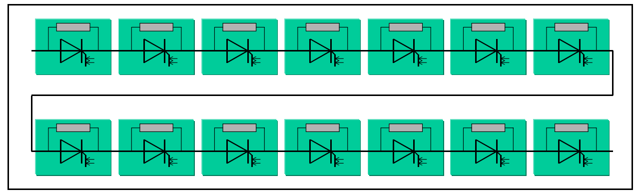

Figure 2: Electrical configuration of the LTT crowbar

For static voltage sharing a simple 1 MOhm high voltage resistor in parallel to each thyristor is applied. This switch is designed for 50kV dc nominal operating voltage.

TEST RESULTS

The first tests have been carried out with a simplified test circuit (figure 3). In this configuration the dynamic behaviour during the starting phase of the capacitor discharge was studied. There is a significant influence of the commutation voltage on the achievable delaytime of the switch (figure 4). In this test set-up under nominal voltage conditions a delaytime of 3.5µs has been achieved (figure 5). Due to limitations of the main circuit parameters the maximum achievable dI/dt under no load condition was 3.5kA/µs.

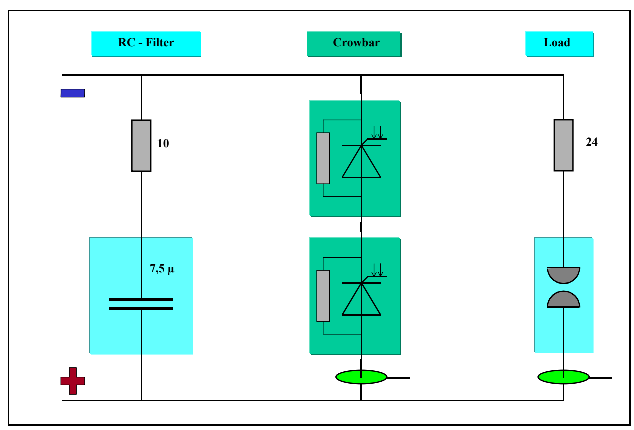

Figure 3: Test set-up

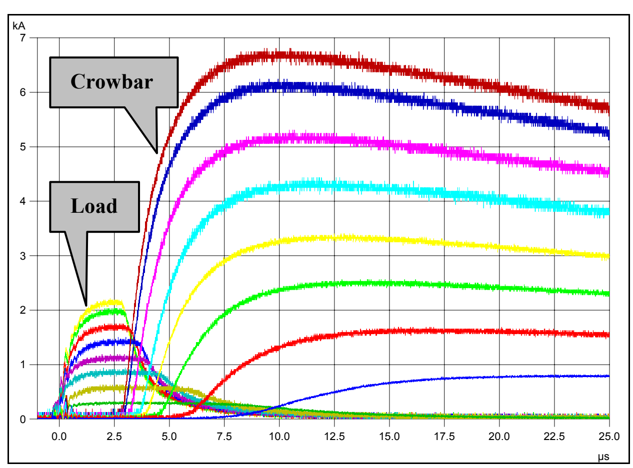

Figure 4: Crowbar operation at different operating voltages (Parameter U_{dc} = 10 / 20 / 30 / 40 / 50 / 60 / 70 / 76 kV)

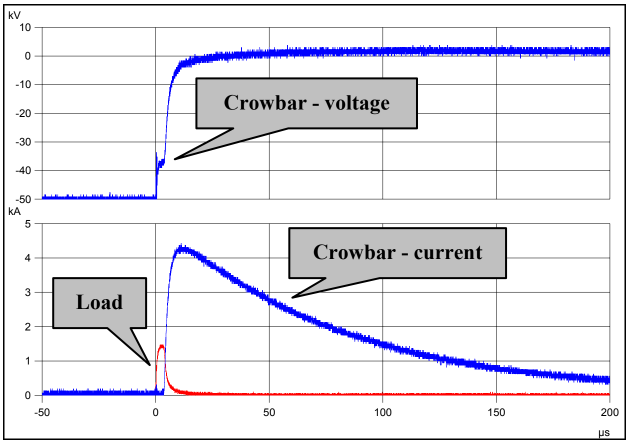

Figure 5: Crowbar operation at nominal voltage

DESY II - INSTALLATION

The new LTT crowbar is planned to operate for klystron protection in the existing DESYII-booster e^+/e^-. This installation is characterized by its large filter capacitor of 240µF at 50kV dc. The main components are shown in figure 8. The three sections (Power-Supply, RC-Filter and Klystron Hall) are linked with appropriate high voltage cables. The cable link between the capacitor bank and the crowbar has to be considered regarding dynamic behaviour of the circuit (figure 6).

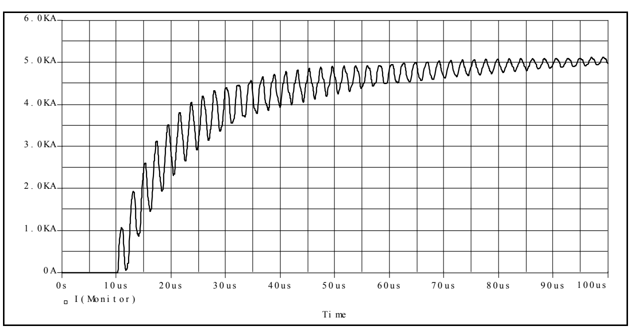

Figure 6: Simulation of the starting edge of the Crowbar current under noload discharge conditions.

Near the end of the discharge process of the capacitor the power-supply has loaded its smoothing choke. This stored energy must be dumped by the crowbar. It leads to additional and very significant charge transfer with a relatively low but long current waveform (figure 7). In this application the total charge transfer is about 30 C, where 12 C is the part delivered by the capacitor bank.

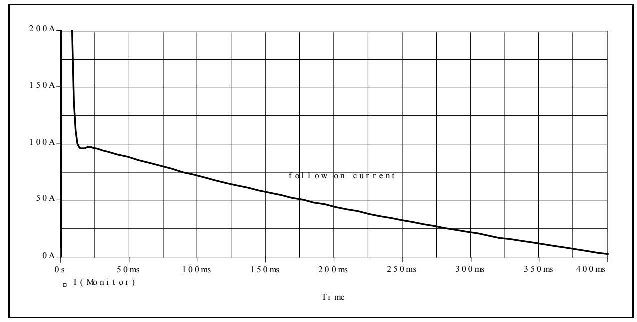

Figure 7: Simulation of the so-called follow through-current introduced by the power-supply smoothing choke.

The operation of the crowbar inside the DESY II – installation will be investigated in future tests.

CONCLUSION

Light Triggered Thyristors are strong candidates for high voltage crowbar applications, where high charge transfer is required. Their main advantages are simple insulation in series connected assamblies due to optical triggering and high charge transfer capability. Sufficient voltage margin leads to reliable HVDC operation. Special care has to be taken selecting the main circuit parameters to achieve optimized switching behaviour, namely the commutation voltage, dI/dt limits and sufficient damping in the main circuit.

REFERENCES

[1] J. Dorn, U. Kellner, F.-J. Niedernostheide, H.-J. Schulze, “State of the Art Light Triggered Thyristors with Integrated Protection Functions”, Power Electronics Europe Issue2, P.29-35, 2002

[2] eupec GmbH, “Technical Information, Phase Control Thyristor, Application Notes” Rel. 2.1, Nov. 2000

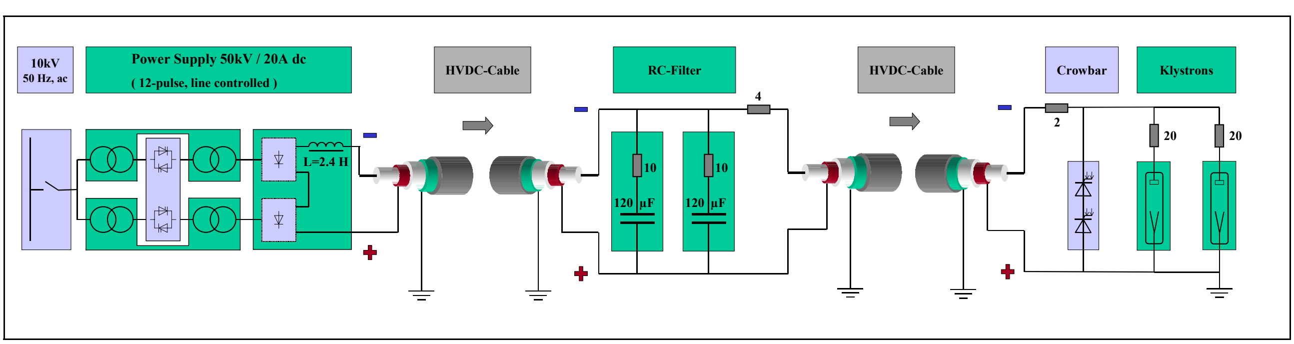

Figure 8: DESY II – Installation consisting of 3 sections (Power Supply, RC-Filter and Klystron Hall)