HIGH CHARGE TRANSFER OPERATION OF LIGHT TRIGGERED THYRISTOR CROWBARS

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Abstract

High power klystrons are protected by the application of crowbar switches. The closing switch approach is most commonly used. It is characterized by establishing a short circuit path to bypass the klystron fault current. During short circuit operation the crowbar switch must be capable to carry both pulse current of the filter capacitor and follow through current of the high voltage dc power supply. Depending on the main circuit parameters both the capacitor charge and the follow through charge can achieve significant amounts. The application of line controlled and uncontrolled hvdc power converters requires special attention regarding the follow through current charge transfer. This paper presents first practical results of series connected Light Triggered Thyristors (LTT) operating as closing crowbar switches. Measured data are discussed, which have been obtained from the DESY-II installation operating with thyristor controllers and the PETRA installation operating with uncontrolled rectifiers. Beside the pulse operation the follow through current capability of the crowbar is pointed out.

INTRODUCTION

Light Triggered Thyristors for klystron protection applications have been introduced in [1]. Two types of these LTT stacks were brought into operation within two different installations to replace triggered spark gaps. The charge transfer requirements of the crowbar switches are determined by the two different types of hvdc powersupplies.

DESY-II INSTALLATION

The main parameters of the DESY-II installation are given in figure 1. It is characterized by operation of a line commutated thyristor converter in combination with an uncontrolled diode rectifier, a significant dc choke and a very large smoothing capacitor at the dc output. The LTT-Crowbar consists of 14 series connected thyristors (2 stacks with 7 thyristors each).

PETRA INSTALLATION

The main parameters of the PETRA installation are given in figure 5. It is characterized by operation of a regulation transformer with a mechanical tap changer and an uncontrolled diode rectifier. The LTT-Crowbar consists of 16 series connected thyristors (2 stacks with 8 thyristors each). Tests have been carried out at the lowest and highest tap changer position, which corresponds to output voltages of 34 kV dc and 70 kV dc respectively. For lack of pulse block capabilities the power supply has to be switched off by the main circuit breaker (mcb).

TESTS

All tests have been carried out with the help of a mechanical driven closing switch instead of a klystron load to initiate the fault current. Therefore it has to be considered that the smoothing choke is unloaded in the beginning of the crowbar operation. Under real dc load conditions higher levels of dc short circuit current magnitudes are expected due to significant core saturation of the dc choke. This should result in reasonable higher charge transfer caused by the choke as part of the follow through charge.

RESULTS

Table 1 shows the measured charge transfer for both installations. Depending on the main circuit parameters the most significant part of the charge is determined either by the capacitor or by the mains. The smoothing chokes introduce additional charge during freewheel operation.

Table 1: Charge transfer at DESY-II and PETRA

		DESY-II	**PETRA U_{dc}=34kV**	**PETRA U_{dc}=70kV**
Capacitor Charge [As]		12.0	0.2	0.4
Follow Through Charge [As]	Mains	0.5	15.1	25.2
	DC Choke	5.8	2.5	5.0
Total Charge [As]		**18.3**	**17.8**	**30.6**

The DESY-II installation feeds most of the charge by the very large filter capacitor. During crowbar operation it leads to a pulse current with a magnitude of 4.2 kA and a high di/dt of about 3 kA/µs (figuere 2). The follow through charge supplied by the mains is small due to the fast pulse block electronic of the thyristor converter. Finally the follow through current fed by the dc choke causes significant additional charge. It is characterized by a low magnitude and long decreasing shape of the current. In this case it takes about 300 ms up to the end of the charge transfer operation (figure 3). The resulting load charge during protection operation is given in figure 4.

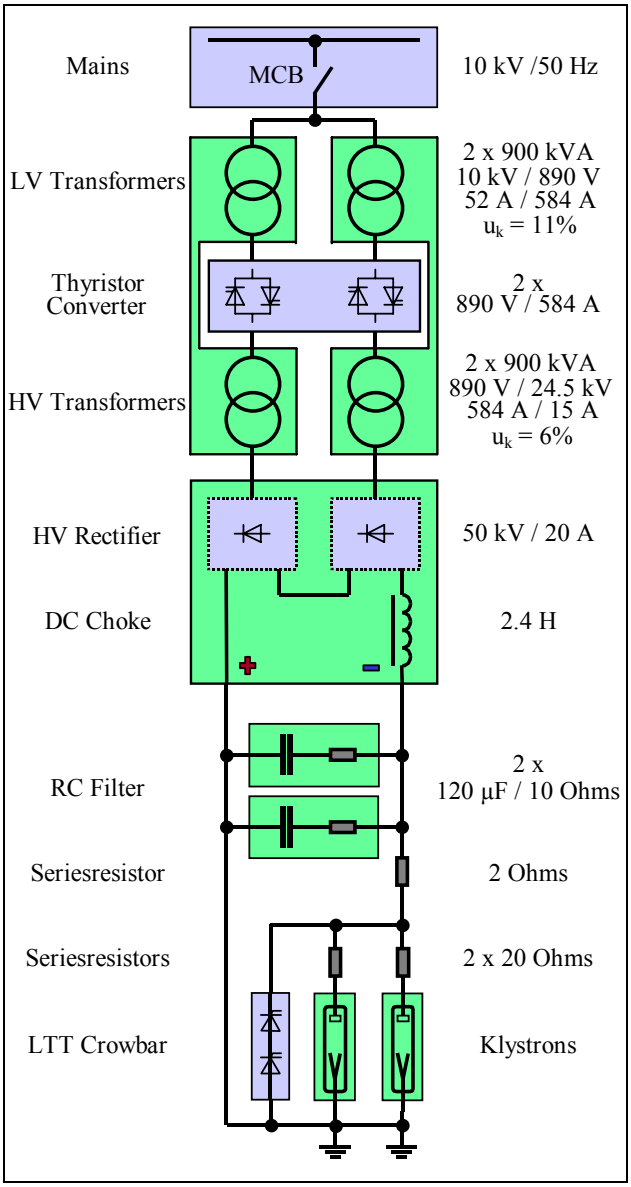

Figure 1: Main circuit diagram DESY-II installation

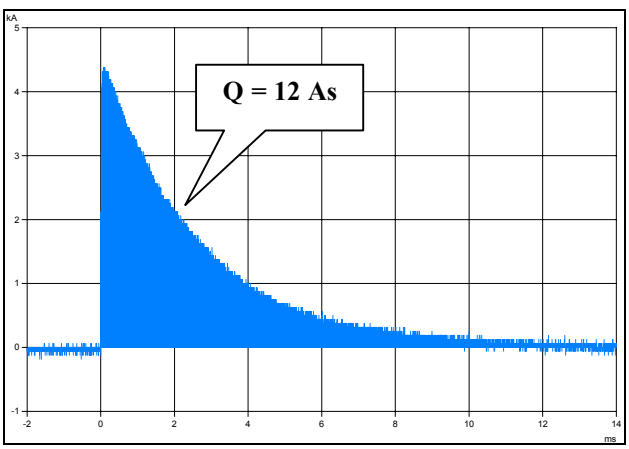

Figure 2: Capacitorcharge DESY-II installation

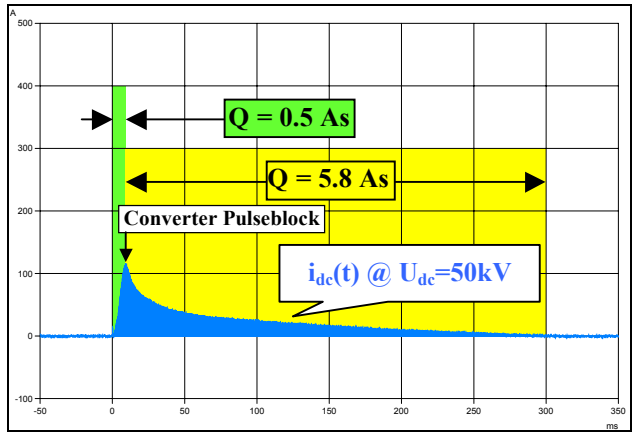

Figure 3: Follow-Through-Charge DESY-II installation

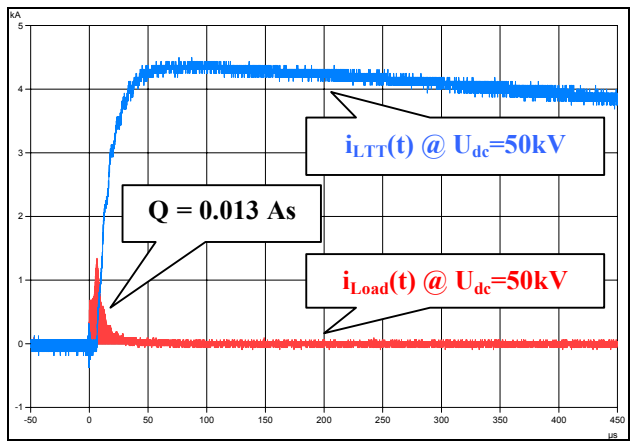

Figure 4: Loadcharge during protection operation DESY-II installation

The PETRA installation drives only a small capacitor charge (figure 6). It is a high but very short pulse current compared to the pulse duration of the total short circuit current. The most significant part of the charge is fed by the mains during short circuit operation of the power supply (figure 7). This is unavoidable because of the switching behaviour of the mechanical main circuit breaker. The short circuit impedance of the regulation transformer changes with the tap changer position. Depending on this position at short circuit time the magnitude of the short circuit current varies considerably. Influenced by the characteristic of the protection electronic, the main circuit breakers switching time and the freewheel operation of the dc choke the total time of charge transfer is in the range from 170 ms up to 210 ms. Due to the high magnitude of the dc short circuit current the follow through charge by the dc choke is still significant. The resulting load charge during protection operation is given in figure 8.

CONCLUSION

Charge transfer requirements of closing crowbar switches strongly depend on the technology and the main circuit parameters of the power supplies used. Obviously the capacitor charge introduces high dynamic stress.

Follow through charge as part of the total charge to be transferred is fed by the mains and any dc choke. It is characterized by low current magnitude but long decreasing pulse shapes.

Light Triggered Thyristors are well suited to fulfil all these requirements in high voltage crowbar applications. Their main advantages are simple insulation in series connected assamblies due to optical triggering and high charge transfer capability. Their pulse current capabilities during capacitor discharge operation are more than sufficient. Their dc current capabilities during follow through charge operation make LTT's best suited for this kind of application.

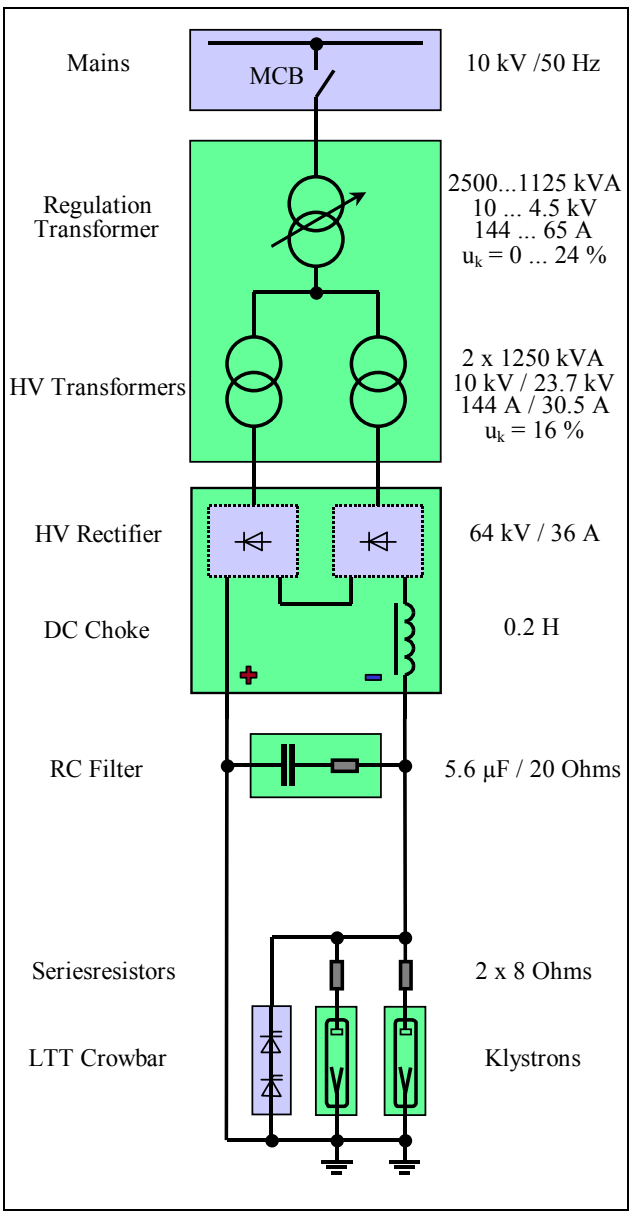

Figure 5: Main circuit diagram PETRA installation

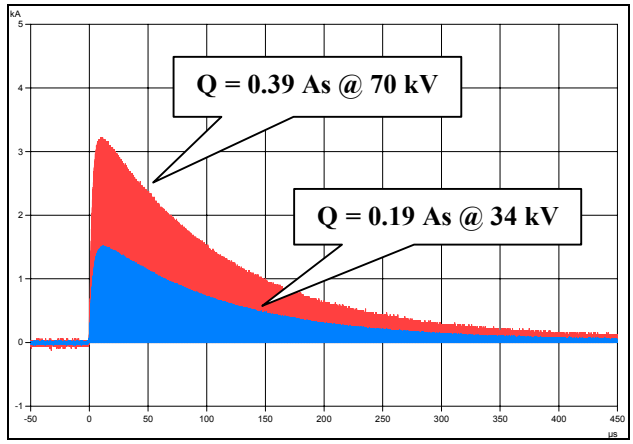

Figure 6: Capacitorcharge PETRA installation

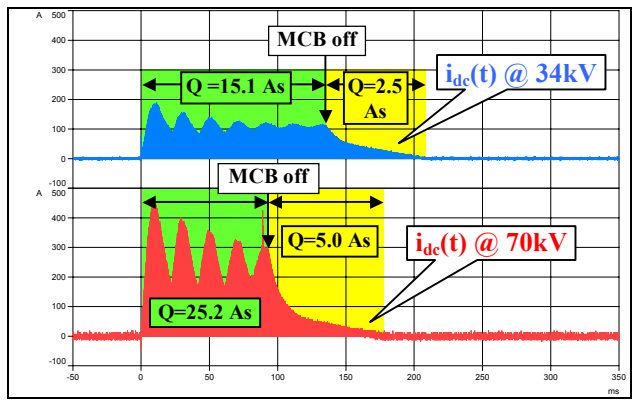

Figure 7: Follow-Through-Charge PETRA installation

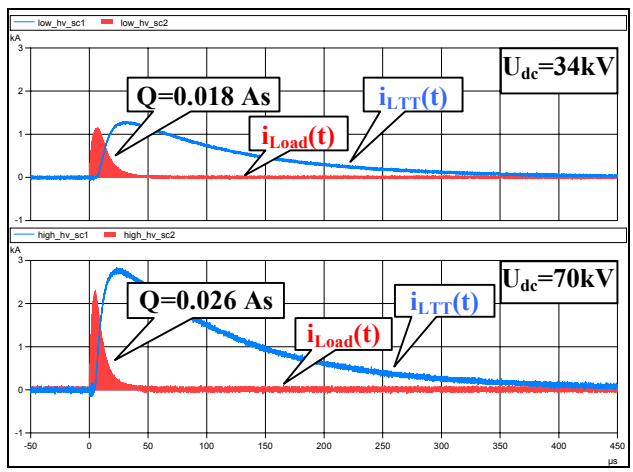

Figure 8: Loadcharge during protection operation PETRA installation

REFERENCES

[1] W. Merz, J.P. Jensen „Light Triggered Thyristor Crowbar for Klystron Protection Application", Proceedings of the PAC 2003, pp. 749-751