AUTOMATED GTO MEASUREMENT, VALIDATION AND STACK SELECTION SYSTEM FOR THE LHC BEAM DUMPING SYSTEM

Article Id: #172

T. Stadlbauer, V. Senaj, CERN, Geneva, Switzerland

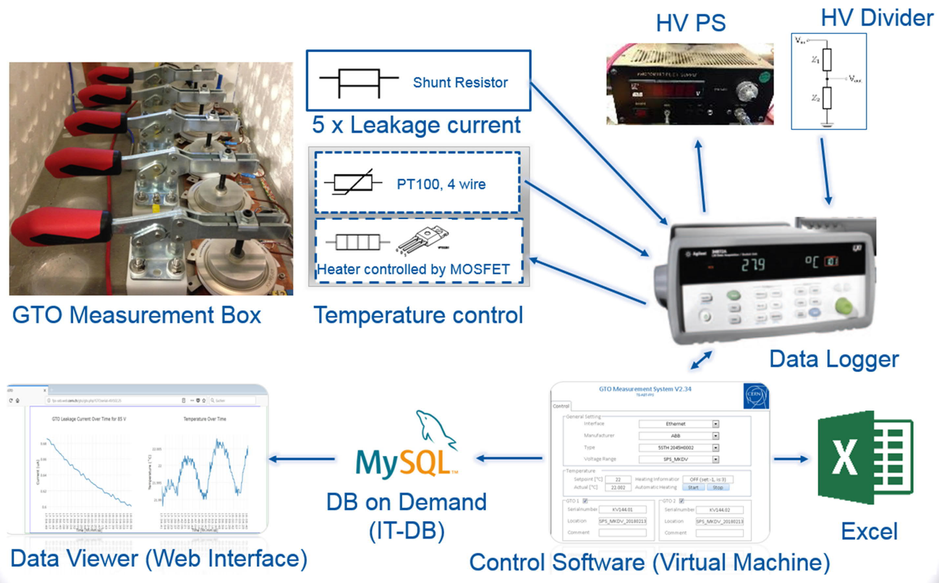
Abstract

The LHC Beam Dumping System (LBDS) is a safety critical system ensuring extraction and safe disposal of LHC beams on dedicated graphite core dump blocks. It comprises 15 extraction and 10 dilution kicker generators per beam and generates up to 1 MA total current at 7 TeV beam energy. Both extraction and dilution generators employ similar stacks with 10 series connected GTO like thyristors as the main switches. To ensure safe operation of the GTO stack, the individual GTOs within the stack have voltage-sharing resistors and are continuously monitored with the goal to detect failure of an individual GTO. The monitoring system compares the voltage drop over the full stack to the voltage drop of the GTO in the lowest position within the stack and generates an alarm/interlock in case of abnormal behavior. The accuracy of the voltage surveillance system can be compromised by individual GTO leakage current variations if the latter is too high, compared to the current in the voltage sharing resistors. To minimize this risk, the Automated GTO Measurement and Stack Selection System (AMSSYS) was developed. It is based on simultaneous leakage current measurements of 5 GTOs at multiple (6) voltage levels within our dynamic range (100 V – 3 kV). AMSSYS selects automatically a set of 10 GTOs with best fitting parameters for one stack. These GTOs then all have a very similar behavior over the whole voltage range at the nominal operational temperature. This selection procedure minimizes forward blocking voltage (VAC) variations within the stack. The risk of a false detection of a GTO failure was significantly reduced, the sensitivity and reliability of the LBDS stack monitoring was improved. This paper outlines the development and design of AMSSYS and presents and compares different test programs for the GTO selection process.

Introduction

A dedicated selection procedure has been established to assemble GTO stacks, which provide a stable behavior to the LBDS stack monitoring system. All GTOs are measured at the manufacturer for prequalification and are re-measured at CERN according to special requirements. In the past this was a manual process with high manpower demands (30 min per GTO). To reduce manpower needs, to avoid human error, to improve stability and accuracy AMSSYS was developed. AMSSYS characterizes each GTO according to the intended use. The stack selection uses the measurement data to automatically select best fitting stacks.

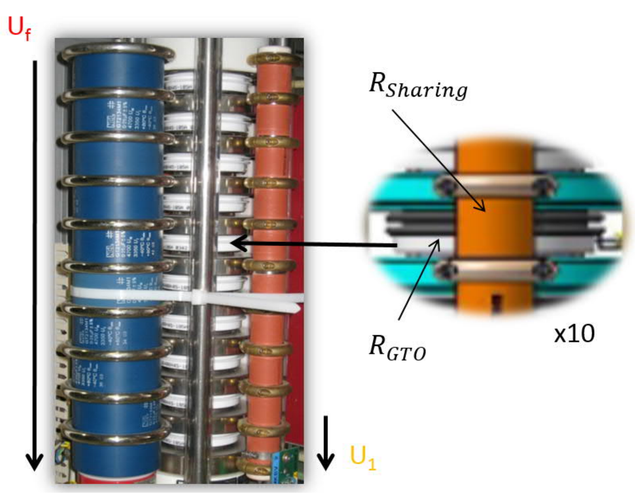
AMSSYS



Design of AMSSYS

- The main acquisition unit is a standard (Keysight® 34970A) data logger.
- Measurement data is stored in MySQL® database and can be displayed by web interface.
- For each GTO a test protocol is automatically generated.
- A stable DC high voltage photomultiplier power supply for testing the GTOs.
- Five GTOs at multiple predefined voltage levels can be simultaneously measured.
- The individual leakage currents are measured by shunt resistors in the return current path.
- The temperature is stabilized to 27 °C ±25 mK by means of a proportional integral closed loop regulation with 4 wire PT100 and PWM controlled MOSFET switch.

GTO Stack

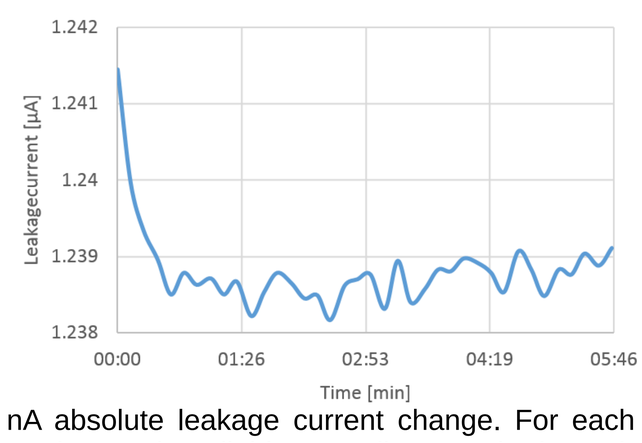


LBDS stack with snubber capacitors (blue), voltage sharing resistors (red) and GTOs (white)

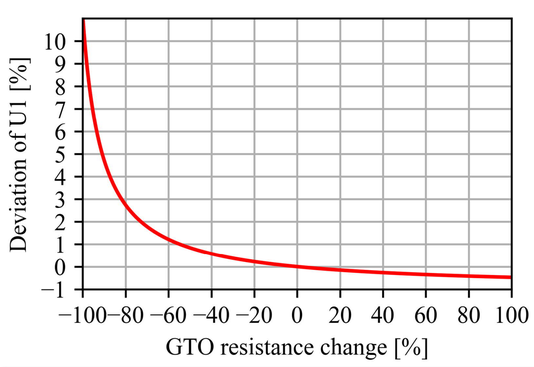
A GTO stack for the LBDS consist of 10 series connected GTO like thyristors (ABB® 5STH 2045H0002).
Peak off state voltage of 4.5 kV
Maximum peak current rating of 80 kA.
To improve the voltage sharing between the individual GTOs static voltage sharing-resistors (5 MΩ parallel to each GTO) and dynamic voltage sharing snubber capacitors (250 nF in parallel to each GTO) are used. The nominal operating voltage range is between 210 V and 29 kV for MKD.

GTO Measurement

The GTOs are clamped with a force of 1 kN into the box to assure good silicon wafer island contact to the cathode inside the press pack.
The gate is short-circuited to the cathode.
For the LBDS system, the GTO measurement sequence starts from the highest voltage towards the lowest: 3 kV, 1 kV, 500 V, 200 V, 100 V and for the MKB system as well at 50 V. The stability criterion is set to less than 1 % leakage current change in 5 min or less than 10 nA absolute leakage current change. For each voltage, the leakage current is recorded over time and available as a diagram via the web interface.

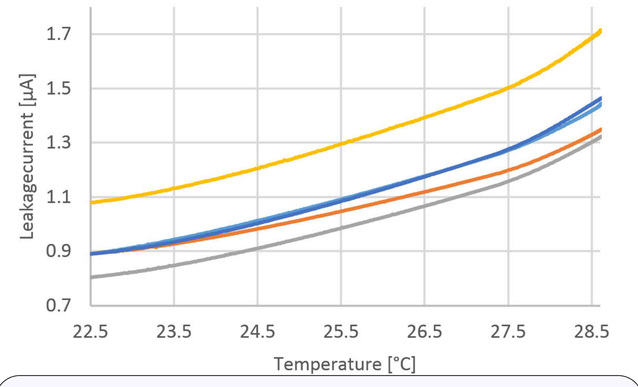


GTO Stack Monitoring System

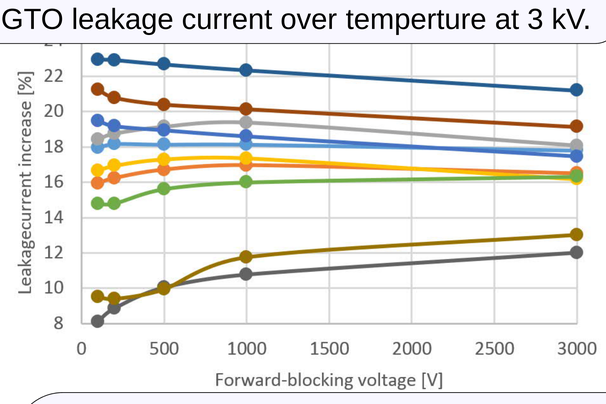


Variation of voltage U1 (bottom GTO) over resistance change of one of residual 9 GTOs

- The stack monitoring system compares the full stack voltage Uf with the voltage drop U1 of the ground referenced GTO in the lowest position.
- In the static voltage blocking state, the ratio U1/Uf is 10%.
- GTO aging or failure indicated by a leakage current change of an individual GTO can be detected and an alarm or an interlock is generated.
- In case of a short circuit of one of the residual 9 GTOs the voltage U1 will change by 11 % (Fig. 2) in case of an open circuit by 11%; in case of short circuit of the bottom most GTO the voltage U1 falls to zero.
- The accuracy of the voltage surveillance system can be compromised by individual GTO leakage current variations e.g. with temperture if the latter is too high, compared to the current in the voltage sharing resistors. Therefore, it is important to select a stack with similar individual GTO behaviour.



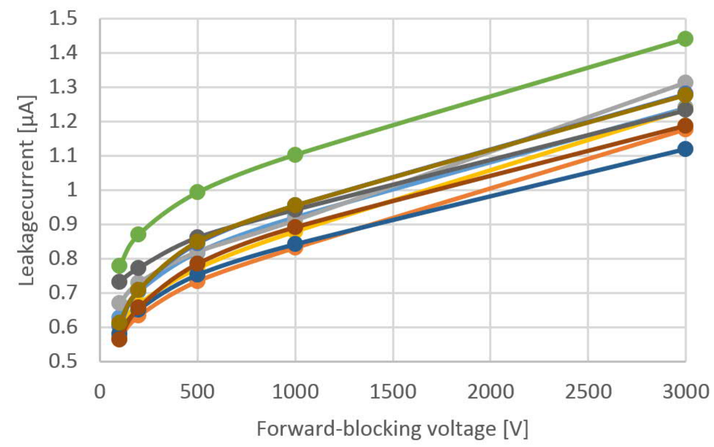
GTO leakage current over temperture at 3 kV.



Relative leakage current increase over voltage for 2 K temperature increase from 27 °C to 29 °C for one stack.

Stack Selection

- To select the best possible stacks based on the GTO measurements an automatic selection was implemented.
- The user can define the maximum and minimum GTO resistance and the maximum settling time for the leakage current stability criterion to preselect GTOs.
- The automatic selection searches through all available GTOs in the database and selects those which fit the preselection.
- AMSSYS picks out the combination with minimum deviation from the ideal Uf/U1 ratio over the whole operating range.



Calculated change of U1 with temperature

Voltage [V]	Deviation of U_1 from ideal voltage [‰]	
	27 °C	*29 °C*
3000	-0.020	0.001
1000	-0.015	0.039
500	-0.057	0.060
200	-0.175	0.135
100	-0.324	0.196

Conclusion

An automated GTO measurement and stack selection system has been developed for the selection of switches for the safety critical LBDS generators. The developed system outlined in this paper significantly reduced the time needed to characterize the individual GTO's. Furthermore, it increased the measurement accuracy and final GTO selection precision. An appreciated benefit of the automated process is the automatically generated test reports and the increasing database. Up to date more than 900 GTOs have been measured and components for 57 stacks have been selected all together saving more than 90 person days compared to the previously manual process. Future activities foresee not only the evaluation of newly bought GTO batches but also during the upcoming 2nd long shutdown of the LHC the measurement of more than 500 GTOs currently in operation in the LBDS. The Comprehensive then database will certainly allow for better analysis of operational anomalies and carries potential information for further improvement of selection and operational parameters.