A NOVEL DISCHARGE RESISTOR DESIGN FOR HVDC CABLES WITH HIGH ENERGY CONTENT

Michael **GAMLIN**, Rany **DEEK**, Juriy **PACHIN,** Tobias **MÜLLER**; Haefely AG, (Switzerland), mgamlin@haefely.com, rdeek@haefely.com, jpachin@haefely.com, tmueller@haefely.com

Marc **KLEMM**, Sebastian **CONDE**, Jannis **KUNTZE**; HTWSaar, (Germany), marc.klemm@htwsaar.de, sebastian.conde@htwsaar.de, jkuntze@htwsaar.de

ABSTRACT

A HVDC test system is designed for high DC voltages up to several hundreds of kV and providing moderate DC currents up to several tens of mA. After testing, HVDC cables need to be discharged in a reasonably short time, meaning within a few minutes. In particular, the time during which the cable is tested with a voltage higher than its rated voltage shall be as short as possible. The discharging time of a HVDC cable is simplified calculated by using its time constant τ which is the product of the discharge resistance R and the cable capacitance C_{cable}. After the time duration of 5 times τ the HVDC cable is considered as being discharged (99%). The challenge is to combine a fast discharging time of a few minutes while maintaining a low DC leakage current of a few mA or even less during testing. The paper describes a new discharge resistor which is filled with deionised water adjusted to a specific water resistivity. The water resistance can be adjusted in a wide resistance range. The discharge resistor is electrically disconnected during the DC test of the HVDC cable and does not draw any DC leakage current. At the time of the discharging the electrical connection will be established remotely triggered by a radio control either by a whip switch or by a steel stretch band in a pipe. The single discharge resistor can handle discharge energies of up to 60 MJ at 1000 kV DC. Due to the versatile resistor design a parallel connection of up to 3 resistors is possible (180 MJ possible discharge energy). The discharge time of high energy HVDC cables will be less than 5 min.

KEYWORDS

Discharge resistor, HVDC cables, fast discharging times, high discharge energies, no leakage current, versatile design

INTRODUCTION

525 kV HVDC cables are suitable for power transmissions above 2 GW. The 525 kV SuedLink for example has a cable length of about 700 km. The capacitance per km *C'* of a 525 kV, 3000 mm^2 XLPE copper cable is about 0.24 µF/km which is in total C_{tot}= 168 µF. The capacitance per km of a mass impreganated (MI) Kraft paper HVDC cable is with about 0.315 µF/km even higher. The recommended DC voltage for the test after installation according CIGRE TB 496 [1] is $1.45{\cdot}U_0$= 761 kV at U_0= 525 kV and $1.85{\cdot}U_0$= 971 kV at U_0= 525 kV for the routine test. The stored energy of a 700 km long 525 kV XLPE HVDC cable during the after installation test is in the range of $0.5{\cdot}C_{tot}{\cdot}(1.45{\cdot}U_0)^2$= 49 MJ. A fast discharge device for HVDC voltage up to 761 kV respectively 971 kV for discharge energies in the range of 50 MJ is required. A novel discharge resistor design with two different connecting units up to 1000 kV DC and discharge energies up to 180 MJ is introduced. The HVDC cable is only at the time it needs to be discharged electrically connected to the discharge resistor. Hence, no additional DC leakage currents due to the discharge resistor will be apparent during the cable testing.

TECHNICAL DATA DISCHARGE RESISTOR

Rated voltage:	1000 kV DC
Parallel resistors *n*:	1, 2, 3
Rated resistance at 20°C:	600 kΩ/*n* ± 5%
Liquid conductivity:	0.9 µS/cm at 20°C
Specific heat capacity:	3.5 kJ/(kg·K)
Rated discharge energy at ≤ 25°C :	(1x 60 MJ) x *n*
Liquid temperature coefficient:	6.86 %/K (*T* ≥ 20°C)
	3.81 %/K (*T* < 20°C)
Liquid volume:	290 l
Minimum creepage distance:	13030 mm
Minimum arcing distance:	3400 mm
Operation temperature:	-20 °C … 95 °C

Due to the versatile design of the liquid filled discharge resistor, up to 3 units can be assembled in parallel connection on the base. Depending on the configuration special adaptatations for the HV electrodes and the connecting device are required. The conductivity of the liquid, a mixture of deionised water and an appropriate antifreeze, is adjusted by desolving an appropriate salt type.

The liquid resistance acts as an adiabatic energy storage which needs about 1.5 days to cool down from 95°C to 20°C. The environmentally friendly and biodegradable antifreeze allows an operation/storage down to -20°C.

A remotely connectable discharge resistor helps during the after installation test of HVDC cables to keep the time above operating voltage level as short as possible to avoid unnecessary test stress for the cable (Fig. 1). The actual HVDC cable discharge is even faster than the simplified $5{\cdot}\tau$ ($\tau = R{\cdot}C_{cable}$) calculation (99% discharged) due to the temperature dependency R(T) of the discharge resistance (Fig. 2, Fig. 3). With ongoing cable discharge the liquid resistor is heating up and its resistance is decreasing.

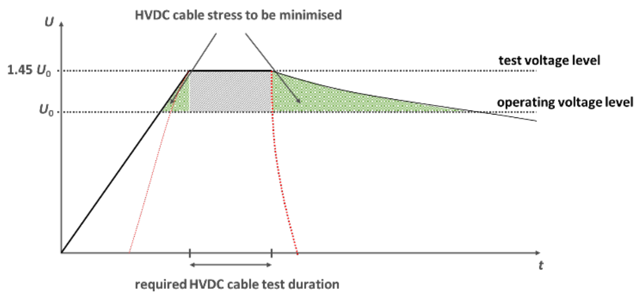

Fig. 1: Test procedure HVDC cable after installation