Modular DC test system for testing long DC cables including a fault location system

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ABSTRACT

Due to the increasing use of DC transmission systems (HVDC) in Europe with voltage levels in the range of 150 kV up to 525 kV, the demand for modular and mobile DC test systems has risen sharply over the last 10 years. DC cable systems (mainly based on extruded cables) and their components must be tested. In order to carry out the development, type, factory tests and on-site tests of extruded DC cable systems, the demand for mobile, modular and powerful DC test systems increased accordingly. Additionally for the prequalification tests, a DC plus LI/SI voltage has to be applied. This paper will present the use of such modular and mobile DC test sources (400 kV modules) for the test tasks above mentioned. The strong requirements for test voltages up to 2200 kV, DC currents up to 80 mA, continuous operation up to one year and on-site tests on very long DC cables (up to 800 km) are safely and economically realized by appropriate series and parallel connections of DC modules. Appropriate protection concepts and components enable the safe execution of superimposed voltages. With water-controlled discharge resistors, the safe discharge of very long DC cables during on-site commissioning tests will be presented too. In combination with a precise fault location measuring system not only a pure DC test can be performed, in case of a breakdown the fault location measuring system enables in addition a precise location of the fault. Examples, such as a test on a DC subsea cable, placed on a turntable and a so-called reference test on a laid DC subsea cable with a length of more than 100 km demonstrate the effectiveness of this fault location concept.

KEYWORDS

Modular DC test system, fault location, TDR, DC cable, on-site test, discharge resistor

INTRODUCTION

The IEC 60060-1 standard defines requirements for the “quality” of DC test voltages [1]. Various and proven test sources exist for the generation of such DC test voltages. Cascade circuits are normally used to achieve high test voltages (e.g. Greinacher circuit), where the AC voltage of an HV transformer is multiplied with the aid of capacitors and then rectified. The necessary components of the test system (transformer, capacitors, rectifiers etc.) are usually arranged on a basic frame that can be moved together with an air cushion in order to replicate variable test field requirements.

This type of DC voltage test system is only of limited use for on-site applications, as the large number of individual components results in increased difficulties relating to transport and installation effort. Whereas on-site testing has already been the state of the art for AC voltage cables for years [2], [3], it is now also becoming increasingly necessary for DC voltage, [4], [5]. On-site tests are required in particular for HV testing of installed DC voltage cables (subsea cables and land cables). In order to meet the requirements of users for modular, compact and mobile DC sources, a concept for this type of test system has been developed and implemented over the last 8 to 10 years, [6], [7].

Over time, further components have been added to the actual modular DC source so that the requirements of cable manufacturers can be met. These include, among others, discharge resistors for type tests with rapid polarity reversal and safe discharging of very long DC cables. Furthermore, suitable protective elements for superimposed voltage tests are also required. This paper will introduce this test system in different constellations with the individual components.

CONCEPT OF THE 400 KV DC MODULES

In order to build a compact test system with a preferably small footprint, a modular 400 kV DC voltage test system was developed and manufactured a few years ago [6], [7]. Since it is built up from multiple, identical and stackable DC voltage modules, it allows the modules to be connected both in series up to 2200 kV or in parallel in order to increase the charging current. For example, by connecting two 400 kV modules in parallel, the current can be increased from 40 mA to 80 mA. The main components (transformer, pole-reversible rectifier, smoothing capacitor and DC voltage divider) are installed in one insulated vessel, made of fibre-reinforced plastic. A two-way circuit based on Delon (Fig. 1) serves as the basic circuit, which also enables a reduced ripple in the generated test voltage (below 2 %).

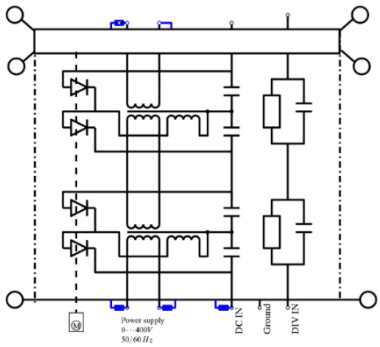

Fig. 1: Circuit concept for the modular 400 kV DC voltage module, see also [6]