

VLF Testing of High Voltage Cables, State of the Art

P. Mohaupt, K. Misteli, H. Geyer
Mohaupt High Voltage GmbH, Austria

Abstract

A new testing method for testing long and extra-long high voltage cables, called Differential Resonance Technology (DRT) is presented. The working principle, the application, as well as the several challenges for onsite testing in an on- and offshore environment are described.

1. Introduction

This is a description of a new method for testing long and extra-long high voltage cables, called Differential Resonance Technology (DRT). Discussed are the working principle, the application as well as the background for onsite testing especially relating to wind farms.

In the last few years, the demand for testing extra-long cables, such as submarine cables has grown rapidly. The traditional testing methods have been complemented by a new testing technology called DRT (Differential Resonance Technology). This method enables testing of extra-long cables with comparably small and light-weight equipment using a very low frequency (VLF) for the test voltage, e.g. 0.1Hz up to 5Hz. This also leads to a significantly lower power requirement of the test source [1].

In a resonant circuit only the losses of the generator's individual components, specifically the high voltage reactor, have to be covered by the mains. The testing power itself remains fully compensated. Typical ratios between the testing power and the input power of resonant test systems start at 50 and go up to 100, depending on the load. Unfortunately, voltage generation based on inductive generation principles such as resonant circuits cannot be used economically for frequencies below 10Hz due to the massive iron cores needed for such a low frequency.

The DRT method for the generation of low frequency high voltage is based on a high frequency voltage whose amplitude is modulated by the desired low frequency. Using a resonator, which is tuned to the high frequency, and a demodulator, the desired low frequency high voltage can be generated [1,2]. The input power required - and in direct relation the size and weight of the equipment - is significantly smaller than for other existing methods.

The theoretical approach was experimentally substantiated by measuring the output voltage and the input power of a prototype unit ultimately designed to produce 200 kV rms. Meanwhile the first units were

manufactured and tested up to 200kV with close to 1 μ F load capacitance.

2. Technical Background

The demand for testing long and extra-long HV and UHV cables such as submarine cables has considerably increased over the last years. Established test techniques using a variable frequency resonant circuit reach their limit due to the size, weight and handling of the required components. A new testing technology based on DRT was recently published by the authors in [1,2]. This testing technology has now been implemented in a unit for field operation up to 200kV (see Fig.1).

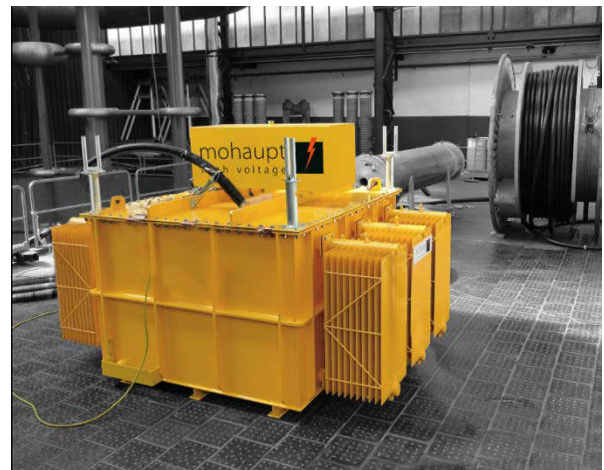


Fig. 1: On Site Test System DRT200-1, 200kV, 1 μ F

Fig. 2 shows the basic working principle of a DRT system. The capacitive load (test object) is charged by a sinusoidal beat frequency oscillation (BFO) over a demodulator setup (switched valve unit - SVU). The beat frequency oscillation consists of the carrier frequency in the range of 1kHz, whose amplitude is modulated by the desired test frequency of, e.g., 0.1Hz or higher. Therein, a resonant circuit tuned to the carrier frequency allows for the simple generation of the necessary high voltages. The output frequency can be easily changed in the range from 0.1Hz up to 5 or even 10Hz by changing the modulation frequency. Higher frequencies, however, require a higher input power of the system which implies that the system components need to be designed for that. The patented [4,5] working principle of a DRT system is described in more detail in [1,2,3,6].

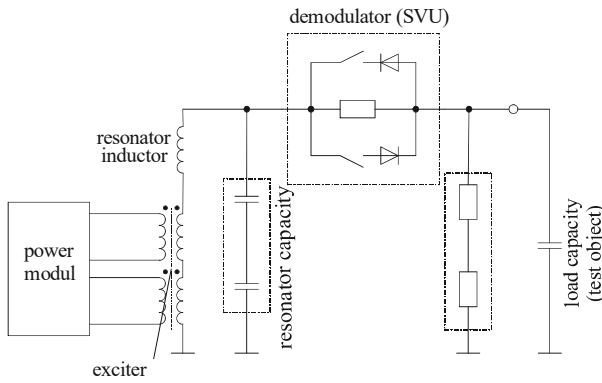


Fig. 2: Working principle DRT system

Additionally, a DRT system can also do testing at DC by charging a capacitive load with a charging current of up to several Ampere. A controlled discharge is achieved by applying the same constant, but reversed, current to the test setup. This is realised in one system together with a standard DRT setup. Fig. 3 shows the voltage at the resonance circuit (pink) and at the output/test object (yellow).

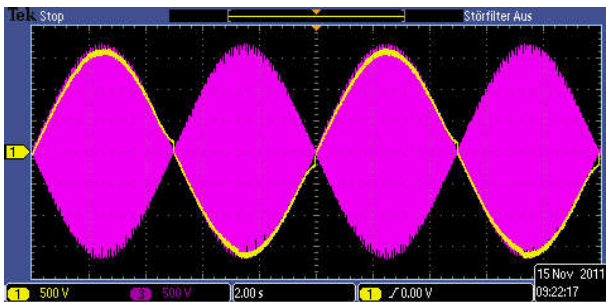


Fig. 3: Resonance Voltage (pink) and output voltage (yellow) at 200kV

3. Application

High voltage overhead lines are increasingly unpopular [7,8] and with the need to extend the capacity of high voltage transmission infrastructure several transmission network operators are planning to build longer cable sections at 400kV and higher. Field-test solutions for these deployments are currently unavailable or impractical to use. Furthermore an entire new infrastructure concept has been designed over the last years to provide transmission connections to large scale off-shore wind farms, requiring AC and/or DC links. The DRT systems will provide an excellent solution for all these emerging testing requirements.

Although all components of high and extra high voltage cables for transmission systems are factory routine tested before deployment, this does not guarantee a flawless operational start or continued operations for the complete transmission system. The dependency on a high voltage infrastructure is ever increasing and disruptions in transmission are affecting more and more users, hence becoming less accepted. The change in grid topology resulting from the increasing amount of renewables installed, adds to the complexity of the situation. With the trend to deliver longer cables without joints to reduce time, effort, cost and – at the same time – increased reliability of the cable system it is a logical consequence that thorough testing of the completely installed system is required. The network owners and operators usually do not accept anymore the traditional existing solutions such as “24 hour soak tests” or partial testing of systems as a final test. The DRT technology provides a very cost effective, fast and technologically simple and reliable solution to this problem.

4. Economic Considerations

In comparison to land-links, failures on offshore links have a much higher impact for 2 main reasons: Longer repair times on complex underwater or offshore installations result in higher loss of revenues and actual repair cost are very high due to special equipment and engineers required to perform the underwater and offshore inspections and repairs. It is also obvious, that a disruption in cash flow due to non-delivery can have severe impact on a network operator’s financial results. High voltage transmission cables on land on the other hand are almost always integrated into an existing grid-structure, which is designed with certain resilience to avoid the impact of cable or line disruptions. Based on these criteria the impact of failures in offshore connections is significantly higher than those for comparable land-cables.

5. Offshore Links

To understand the need for after laying testing, let’s look at the off-shore wind farm power transmission connections. Initially most wind farms were relatively close to the shoreline, and several windmills were connected to one transmission link. Power transmission for the “close” wind farms was implemented by providing multiple connections at 20kV or generation voltage, which at land was either connected into the distribution grid, or was transformed on-shore to a higher voltage and connected to the transmission grid.

With the higher capacities per windmill this practice became unsuitable, and higher voltage connections were installed to overcome capacity limitations and avoid

excessive losses. This required the installation of offshore transformers at a central connection point and a high-voltage AC connection to the transmission network on-shore, a practice that has now been operational for some years [9].

With even larger wind farms and even further offshore the transmission links became more powerful and longer, driven by the continuously increasing power of the individual windmill and the number of windmills within the parks. These powerful links served multiple wind farms off-shore and required a direct connection to the high voltage transmission grid to avoid bottlenecks in the integration with the existing transmission infrastructure. These very high capacity wind farms currently favour HVDC connections to the shore and the use of AC connections for infield cables.

As a consequence of this development the need for testing offshore high voltage AC and DC cables has strongly emerged, increasingly even more supported by latest developments in wind farms technology.

6. On Site Testing

Long lengths MV cables are tested already for several years with MV VLF test equipment. Testing longer lengths high voltage cables outside a laboratory or factory is still a challenge today. Clustering several modules of test equipment onshore is a logistical, technical and economical mission. Performing these tests in an offshore environment is beyond any economic, technical and operational feasibility. Severe weather conditions with seawater swept over the test setup can delay a test for several days or weeks, a totally unacceptable risk and the planning nightmare of each project manager. This has led to a widespread acceptance of “24 hour soak tests” as the in use test-method.

The DRT equipment mentioned above, overcomes all these limitations, and can carry out onshore and offshore tests, using VLF and DC in the same totally encapsulated test equipment, completely weather agnostic.

7. References

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