Onsite testing of offshore array cables

Generic layout of designed offshore RTS

The design, installation and commissioning of offshore wind farms are facing several challenges for the inter array grid. The continuously increasing power ratings of the individual wind turbines leads to increasing operating voltages (Um), from 36 kV to 72.5 kV for the inter array cables to reduce operating currents and therefore thermal losses. As these cables are designed as high voltage and not as medium voltage cables, the after-installation testing should be done by resonant test systems (RTS) as defined in IEC 63026:2019 and CIGRE TB 841.

HIGHVOLT, as a market leader, has a track record of more than 260 RTS systems in operation worldwide and developed a completely new RTS system for offshore operation. As offshore conditions are quite different to conventional onshore onsite tests, the test system must be adapted to the specific requirements for transportation and operation offshore.

Discussing these requirements with all stakeholders, like platform operators and test service providers, a basic conformity with offshore standards was defined, compliant with DNVGL-ST-E 273. Additional stakeholder discussions brought up the continuously increasing importance of the specific operating procedures during transport, erection, and operation of the high voltage test system on the offshore substation (OSS).

Cable testing methods

Establishing cable manufacturing methods guarantees a high standard on the cable itself and factory testing keeps the risk of failures in the cable insulation close to zero. Failures in the field are most likely related to two sources: external impact to the cables, or anchor, and installation issues through process deviations.

Deviations in installation routines are likely to be directly correlated to premature termination failures, resulting in outage and potential loss of revenue. Anticipating that the typical 66 kV array cable system premature failures might be concentrated on these end terminations, robust testing of the cable system, as installed, is important to ensure reliable continuous operation over the design life.

The highest failure probability is given for the incorrect handling of the termination components related to the field grading along the dielectric interface between cable insulation and termination insulation. Accidentally included air bubbles, dust, or uneven surfaces, combined with too little or too much installation grease might lead to imperfections capable of initiating partial discharges (PD) when an electric field is applied.

Due to the stochastic physical process and the related boundary conditions, the number of polarity reversals is directly correlated to the probability to initiate a partial discharge at the incriminated cable termination. Therefore, RTS is advantageous to other test methods, like very low frequency (VLF) and damped AC (DAC) for the detection of installation failures. It is noted that IEC 63026:2019 does not recommend VLF testing of this voltage class, nor permit the use of DAC. For medium voltage cables with Um < 36 kV, DAC and VLF have their merits for diagnostic measurements.

The principle of the RTS (Figure 1) is that of a frequency tuned resonant circuit, in which the cable capacitance is energised by the feeding source. Combining it with a resonant reactor forms an oscillating circuit, providing a large output voltage when exciting at resonant frequency. Here, only the ohmic losses of the circuit must be compensated by the power source, meaning long cables can easily be energised. It is very important to note that the oscillating circuit is always forming a sinusoidal voltage of very low harmonic distortion, independent from the frequency or shape of voltage of the feeding source.

Customer requirements anticipated

Most challenging during the development process was the change in mindset. Typically, we are designing the most suitable and most complex test systems, able to cope with today's and anticipate tomorrow's requirements in a test laboratory. The offshore solution is not driven by the features and functionality of the test source and therefore by the compliance with the specific requirements for the impelled processes.

These processes are mobilisation onshore, transportation to and location on the OSS, installation and operation of the test circuit, interferences with other operational processes on the OSS.

The focus was now on mobilization, de-mobilization, and re-mobilization. How fast can the test system be mobilized? What are the demobilization requirements like cleaning, performance check and replacement of consumable materials? And how fast can the test system be re-mobilized after a test campaign?

In terms of transportation and handling, how to guarantee simple transfer from road to marine transport in harbour? How to modularize the system to enable easy transport over open water? Due to the wide range of working conditions on the OSS, how can a flexible footprint of all components be guaranteed? And finally, how do we store all components and parts in the most efficient order to optimize the setup and demobilisation of the test system?

Solution delivered

The lead image shows a generic layout of the manufactured offshore RTS. This system complies fully to IEC 63026 and CIGRE TB 841 [1, 2] and DNVGL E273 [3]. Figure 4 shows part of the system at the roof deck on duty on the OSS.

The technical parameter of this specific test system with two reactors can be found in the following table.

It has to be stated that a conventional setup can be extended up to four reactors in parallel covering a load capacitance of 11.2 µF at maximum test voltage. Assuming a typical 66 kV array cable, testing a maximum string length up to 35 km becomes possible.

Operational experience

In the framework of the test campaign, the test system showed a very good performance. However, the specific agreed requirements and the real operation conditions have shown certain areas for improvements. As this was clear to all stakeholders, HIGHVOLT has offered a revision of the test system after the campaign.

Parameter	Value	Unit	Remark
Rated Voltage	80	kV	
Rated Current	37.5	A	
Rated Power	5000	kVA	Equivalent Power @50 Hz
Weight	3.7	t	Max. weight per unit
Load capacitance per reactor	5.6	µF	@20 Hz

Conclusion

The development of the first successful offshore suitable RTS system for 66 kV inter array cables was mainly driven by the long-term interaction of all stakeholders, especially the OSS operator, the test service provider, and the manufacturer of the test system. During the development, the requirements of the relevant standards were a crucial starting point.

Another important pillar of success was the understanding of the operational requirement for the mobilization of test equipment, the operation on the OSS and the demobilization.

The test campaign was executed in cooperation between the test service provider and the manufacturer. So, the fulfilment of all technical assumptions could be proven under field service conditions. The joint test campaign was crucial to increase the understanding of the importance of apparent minor technical features for both parties. These experiences led to certain optimisations, all related to the reduction of handling complexity, increase of safety, improvement of operational efficiency and technical capability.

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Key features for the success of the product include:

Touch-proof design of high voltage test source. The electrically isolated design of all components of the HV test source enabled parallel working of other processes beside electrical testing, high degree of operational freedom at minimal space requirements.

Weather independent operation of test system. As all power and control connections were made by offshore capable cable connections the complete system could be operated independent from the weather conditions. Using offshore proven coating of all metallic structures even permanent offshore operation during heavy rain, storm and ice periods becomes possible.

Modularity as an enabler of agility and flexibility. The modular design allows the installation and operation of the test system with a minimal mobilisation of workforce meaning two qualified service technicians, including non-planned change requests.

Modularity for safe transportation over open water. Having pre-defined transportation units in accordance with DNV-ST E273 the handling of the HV test equipment is equivalent to other typical service equipment. Sticking to the weight limit of 3.7 t allows hassle-free transportation over open water without additional approvals and paperwork.

Independent voltage measurement at the cable under test: Integrating an additional voltage divider at the connection point enables a safe operation at the cable independent from the HV source at the roof deck.

Integrated partial discharge (PD) measurement: PD measurements are key for a qualitative evaluation of the cable. The PD measurement is optional and will be integrated directly at the connection to the CUT. Utilizing special HFCT sensors, PD measurements on wind turbines at the far end are also possible.

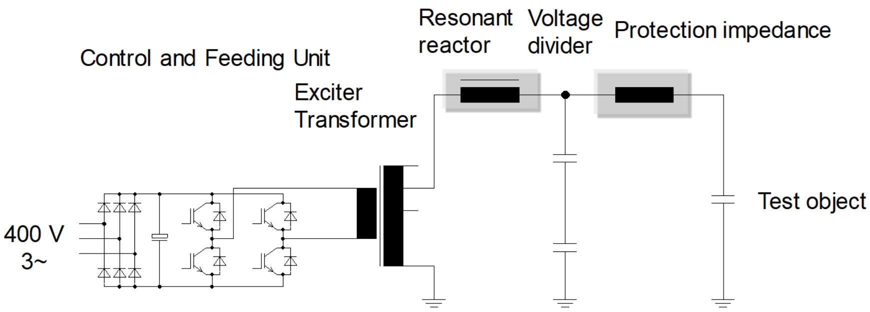

Figure 1 Principle of a resonant test system (RTS)

Setup of RTS at OSS