Reliable Green Electricity

Vibration Test Validates Design Enhancements on Electrotechnical Components of Converter Modules for High Voltage Direct Current Transmission

Introduction

Offshore wind farms, much like drilling platforms, are often more than 50 km off the coast. They are connected to the mainland grid over longer distances using high voltage direct current (DC) transmission systems. These systems and their components, supplied by Siemens Energy, must fulfill extreme demands with regard to reliability and provide a service life of more than 30 years. To achieve this, the electrical energy of numerous wind turbines is “collected” at sea in a local alternating current (AC) grid, then converted to DC using a rectifier, before being transported to land via sea cable. There it is again converted, via an inverter, into AC and fed into the high voltage grid. During operation, the technical systems are subjected to a wide range of stresses and strains. For example, mechanical vibrations in the converter structure arise from its rectification function. The electrical current produces mechanical forces which generate vibrations that could excite eigenmodes in the structure. An awareness of this condition is necessary in order to implement a design that will prevent component overload. The determination of the eigenmodes permits targeted design improvements, the success of which can then be practically verified, using vibration tests.

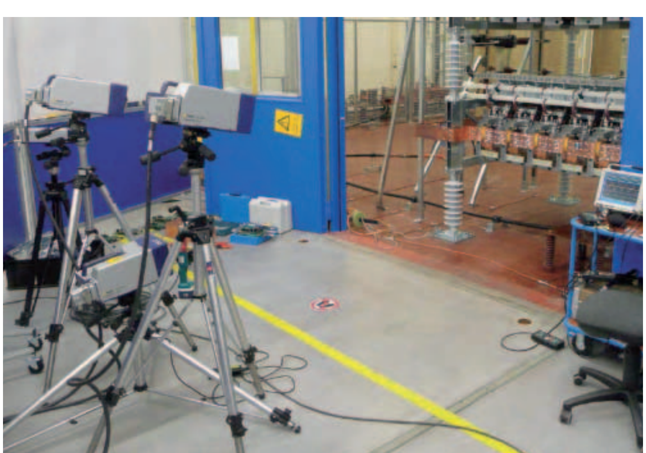

Fig.1: HVDC test facility, scan heads positioned in front.

Fig. 2: HVDC test facility, scan heads set-up for testing the rear side.

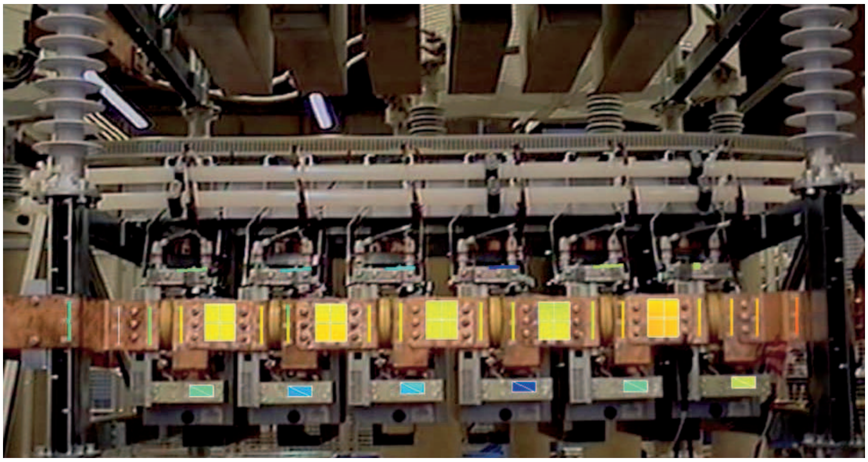

Fig. 3: Vibration modes on the semiconductor modules on the front of the converter.

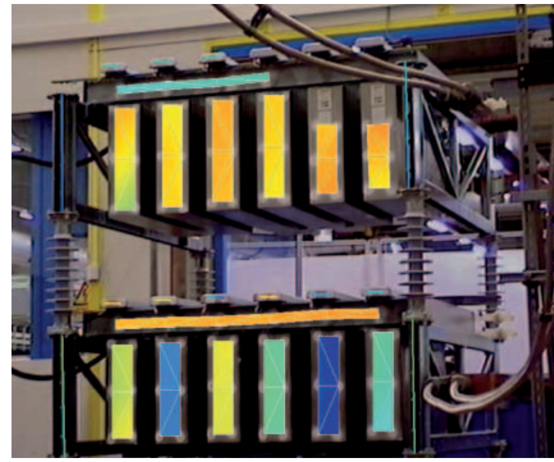

Fig. 4: Vibration modes of the converter measured on the rear side of the power capacitors.

Experimental Set-up

The vibrations occurring on a converter module during operation were measured using a PSV-400-3D Scanning Vibrometer. The module forms part of a test facility which is supplied from the national grid and functions as a "miniature model" with similar characteristics to the original. (fig. 1 and 2). Due to high voltages, much of the measurement instrumentation was set up outside the test area. Only the measuring heads were positioned inside, close to the module. An OFV-505/5000 Single-Point Vibrometer was used as a reference sensor, transmitting its output signal via BNC cable to the data management system (DMS). The reference signal enables subsequent stitching of data obtained from measurements taken from different directions.

Pre-tests

In a first test series, the vibration properties of selected components were investigated. Various positions on the mechanical structure were of interest. Loading spectra had to be determined for qualification prior to design and development.

The measurements took place at various levels up to full load and under many operating scenarios. In total, including setting up and determining the noise levels, some 20 measurements were carried out, each of which lasted 10 minutes. Each measurement comprised 52 measurement points with a frequency span of 800 Hz, a resolution of 1 Hz and 10 averages (complex measurements, i.e. both real and imaginary parts).

Validation Experiment

Additional measurements were made in order to validate vibration-optimized converter modules, comprising six power modules and their corresponding power capacitors. The entire block was initially measured from the front and in the original state under various current loads (fig. 3).

Further measurements were carried out, systematically exchanging various components. Later, additional measurements were performed on the rear side of the converter (fig. 4).

A major advantage was that data from both front and rear measurements could be subsequently combined, resulting in an overall visualization of the vibration characteristics of the entire system.

Conclusions and Outlook

The 3-D scanning vibrometer measurements rapidly provided eigenmode data over large areas of critical converter module components. The customer was highly satisfied with the measurement service provided and the system used, especially the PSV Software, due to its simple operation and visualization tools. Besides the improvement of the design aimed at preventing failure due to the operating frequencies, low frequency resonance vibrations in the Hz-range of the entire system can also be determined, which could, for example, be of importance in earthquake simulations. For this purpose a sufficiently large vibrating table or shaker can be controlled by the Polytec system interface, generating the frequencies required for measurement of complex motion spectra. The 3-D scanning vibrometer shown here can therefore sample the motion of the system and visualize the motion characteristics and areas where resonance may occur.

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