Combined distributed fibre optic sensing: the revolution in managing and reducing risks and costs of offshore power cable

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ABSTRACT

Over the last 15 years, more than 200 million euros were lost to the offshore wind industry, 70% of which due to cable failures. Distributed fibre optic sensing is seen as a mean of managing and reducing such risks. Temperature measurement prevents hot spot failure and localises faults; together with real time thermal rating it helps managing the load. Strain measurement can monitor bending and tension during installation and operation and localise potential failure. Acoustic sensing can also provide fault localisation. When correctly selected and properly specified, these technologies become an efficient way of managing the offshore power cable.

KEYWORDS

Distributed fibre sensing, Distributed temperature, distributed strain, distributed acoustic, DTS, DSS, DAS, real time thermal rating, cable condition, cable integrity, offshore wind, power cable.

INTRODUCTION

Over recent years, the offshore wind industry has seen multiple power cable failures resulting in significant financial loss due to the lack of production and repair costs. Although limited information is publically available, it is estimated that more than 200 million euro were lost to the UK wind industry alone [1], [2].

In this context, recent deployments of Distributed Fibre Optic Sensing (DFOS) demonstrated the potential impact of the technology for risk management and safer operation.

In this paper, the importance of using standards and a common language for the definition of DFOS instruments and parameters is addressed. Then, some field applications are reviewed, together with the key findings, for Distributed Temperature Sensor (DTS) and Distributed Acoustic Sensor (DAS). Finally, potential next steps using Distributed Strain Sensing (DSS) is described.

DISTRIBUTED FIBRE OPTIC SENSING (DFOS) PRINCIPLES

Baskscattering

Distributed Fibre Optic Sensing (DFOS) are based on the measurement of backscattered light from optical fibres [3]. A powerful light pulse, known as Pump, at wavelength λ_0 is launched in an optical fibre. A small amount of the incident power is scattered in all directions due to local non-homogeneities, of which a fraction is guided in the backward direction (towards the pump laser) where it can be analysed.

The scattering signal is made of three components originating from material impurities (Raleigh scattering), thermally excited acoustic waves (Brillouin scattering) and atomic or molecular vibrations (Raman scattering) as shown in Fig. 1.

RAYLEIGH SCATTERING is the interaction of a light pulse with material impurities. It is the largest of the three backscattered signals in silica fibres and has the same wavelength as the incident light.

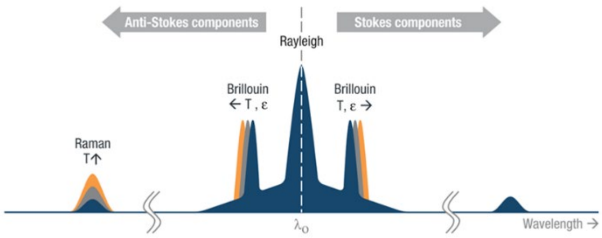

Fig. 1: Backscattered light components of a single mode laser (single wavelength λ_0) light launched in a single mode optical fibre

BRILLOUIN SCATTERING is the interaction of a light pulse with thermally excited acoustic waves (also called acoustic phonons). Acoustic waves, through the elasto-optic effect, slightly and locally modify the index of refraction. The corresponding moving grating reflects back a small amount of the incident light and shifts its frequency (or wavelength) due to the Doppler Effect. The shift depends on the acoustic velocity in the fibre while its sign (positive or negative shift) depends on the propagation direction of the travelling acoustic waves. Thus, Brillouin backscattering is created at two different frequencies around the incident light, called the Stokes and the Anti-Stokes components. In silica fibres, the Brillouin frequency shift is in the 10GHz range (0.1nm in the 1550nm wavelength range) and is temperature and strain dependent.

RAMAN SCATTERING is the interaction of a light pulse with thermally excited atomic or molecular vibrations (optical phonons) and is the smallest of the three backscattered signals in intensity. Raman scattering exhibits a large frequency shift of typically 13THz in silica fibres, corresponding to 100nm at a wavelength of 1550nm. The Raman Anti-Stokes component intensity is temperature dependent whereas the Stokes component is nearly temperature insensitive.

From backscattering to instrumentation

Rayleigh backscattering is used for so called Distributed Acoustic Sensing.

Brillouin backscattering is used either for Distributed Temperature Sensing or for Distributed Strain Sensing. Both the spontaneous Brillouin and the stimulated Brillouin scattering are used, depending on the application, resulting in Brillouin Optical Time Domain Reflectomer (BOTDR) or Analyser (BOTDA).

Raman backscattering is used for Distributed Temperature