



جامعة
ALEXANDRIA
UNIVERSITY



Faculty of Engineering
Department of Electrical Engineering

Advanced Applications of Fiber Bragg Grating (FBG)

**A Thesis submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy**

In

Electrical Engineering (Communication and Electronics Major)

Presented by

Hanan Mahmoud Ahmed Tawfik El-Gammal

**B.Sc. in Electrical Engineering (Communication and Electronics Major), Faculty
of Engineering, Alexandria University, 2011**

**M.Sc. in Electronics and Communications Engineering, College of Engineering
and Technology, Arab Academy for Science, Technology and Maritime
Transport, 2014**

2021

ABSTRACT

Temperature monitoring in high-voltage Overhead Transmission Lines (OHTLs) on continuous basis have become a subject of much interest and research in recent years, since the OHTLs are subjected to various harsh meteorological and geographical conditions which can cause disastrous effects on the lines such as flashovers, line breakings, and even tower collapsing.

Although Piezo-Electric Transducers (PZT) hydrophones are widely accepted and technologically mature in the field of Acoustic Emissions (AE) strain sensing underwater, optical fiber based sensors are gaining more attraction owing to their multiplexing capability, small size, high resolution and sensitivity and immunity to Electromagnetic Interference (EMI).

For the aim of these two advanced applications, a proposed hybrid Fiber Bragg Grating (FBG) system is presented in this research work. This is because the development of the FBG sensing technology became prominent for monitoring of temperature and strain for having several unique advantages compared to the traditional PZT sensors. The proposed hybrid FBG consists of two Apodized FBGs (AFBGs): one Nuttall and one Cos^8 separated by a π -phase shift. This shows an optimum remarkable performance in terms of the reflection properties including high peak reflectivity, narrow Full Width at Half Maximum (FWHM), side lobes suppression, high roll-off rate, good Ripple Factor (RF) and high Detection Accuracy (DA) as well. In addition, an excellent multiplexing capability, high temperature and strain sensitivities and a stable operation over increased temperatures, strain and pressure levels (up to 250 °C, 1000 μ strain and 100 MPa) are of great interest.

Moreover, mechanical analysis and comparisons revealed that the Polymer Optical Fiber (POF) has recorded the highest sensitivity among several fiber types and their coating, making it applicable in the mentioned advanced applications.

A novel temperature monitoring system for high-voltage OHTLs and bus bars in high-voltage substations based on the proposed hybrid FBG is introduced in this thesis. In addition, a novel experimental setup of strain monitoring system for underwater acoustics is proposed based on the proposed hybrid FBG also. Both are simulated on the OptiSystem software (version 14.2) and they proved to have a remarkable better performance when compared to their counterparts in terms of the evaluation parameters, long-term stability, sensitivity, multiplexing, isolation and protection.

This thesis also seeks to provide a remedy for low sensitivity and slow demodulation time problems of the traditional interrogator methods which use Optical Spectrum Analyzer (OSA). Accordingly, a detailed comparative study is performed between several types of interrogators targeting an optimum interrogator for the two mentioned advanced applications. The obtained results reveal that the linear edge absorption filter detection method shows better results among the other types. It has good resolution range with high sensitivity, fast measurement speed, good long-term stability and low cost. But unfortunately, when talking about the multiplexing capability, it shows a remarkable failure. Whereas, the Mach-Zehnder Interferometry (MZI) can come in the second place after the edge filter with higher resolution range with tunable sensitivity, fast measurement speed, good long-term stability, high multiplexing capability and medium cost. Accordingly, both of them could be applicable in the applications understudy.