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Bragg system for temperature monitoring in distribution transformers

Alessandra F. Picanço*, Manuel L.B. Martinez, Paulo C. Rosa

Institute of Electrical Systems and Energy, Federal University of Itajubá – UNIFEI, Rua Coronel Rennó, 07 CEP: 37500-050 Itajubá – MG, Brazil

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ABSTRACT

Heat represents the energy loss occurring in the core and coils of a transformer. The designer must be able to predict the temperature throughout the transformer, in order to correctly determine the amount of copper and silicon steel sheet and the type of cooling ducts and insulation needed to prevent excessive hot spots. This paper presents a pilot design of a distribution transformer monitor using Fiber Bragg Grating (FBG) technology to determine the temperature at 12 points distributed along the LV and HV coils employing three optical fibers. A 100 kV A single-phase distribution transformer was utilized in order to accurately find and measure the hot spot. The thermal equivalent circuit model was built according to the heat transmission process in a transformer. The radiation and convection resistance values of this model are determined iteratively until they border on the FBG measurement results.

1. Introduction

The EPRI (Electric Power Research Institute) carried out research with the Fluoroptic optical thermometer developed by the Luxtron Corporation in 1982 [1]. The aim of the study was to check transformer hot spots through the use of a fiber optic sensor. The fluorescent transmission is used to measure the temperature by phosphor decay time. This sensor is connected to the end of the fiber and a high intensity LED provides the light that carries the information regarding the temperature. The fiber is covered by dielectric material and possesses good mechanical and temperature stress behavior during transformer operation. The fluorescent signal attenuates during sensor service life due to the higher temperature and reduced oil quality, producing, therefore, questionable readings in some cases. One drawback identified was the use of only a single sensor per fiber.

This temperature monitor for a distribution transformer uses Fiber Bragg Grating and presents the possibility of simultaneously measuring several points per fiber.

Bragg Grating is a technique that creates a deformation inside the fiber core, establishing an interference wavelength (frequency). This occurs because the signal is constructive in one direction and destructive in the other. The deformation changes the refraction index of the fiber and the interference wavelength shifts when temperature or mechanical deformation occurs. The laser tuner technique allows verification of up to 30 FBG per fiber and was used for this study.

Transformer temperature knowledge is important to evaluate service life loss and hot spot behavior. It offers parameters to help the designer build an efficient distribution transformer and minimize grid losses.

The temperature monitoring design was applied to a 100 kV A single-phase mineral-oil-immersed distribution transformer, with 3 Fiber Optics and 4 FBG per fiber covering 12 distributed measuring points.

2. Bragg Grating sensor interrogation technique

The choice of sensor interrogation technique in Bragg Grating depends on the application and must take into consideration the frequency bandwidth, the number of sensors required, the temperature range and the dimensions of the measurement system.

The Optical Spectrum Analyzer (OSA) presents the simplest form of directly measuring the spectrum of a sensor's wave peak and wavelength (Wavemeter) (Fig. 1).

The technique based on fixed filters [2] presents low cost and can be of the Fabry Perot model, interferometer and other FBG techniques. The application for dynamic measurements is an advantage but its efficiency is dependant on the source. Fig. 2 shows the system based on Bragg Grating with fixed filters and a large bandwidth spectrum source developed by Leiderman et al. [2]. There is another Bragg Grating with a fixed filter inside the reception device for each

* Corresponding author at: Federal University of Itajuba – UNIFEI, LAT EFEI - Electrical Eng, Rua Coronel Rennó, 07 CEP: 37500-050 Itajubá – MG, Brazil.
Tel.: +55 35 3622 3546; fax: +55 35 3622 3546.
E-mail addresses: alessandra_picanco@yahoo.com.br (A.F. Picanço), martinez@lat-efei.org.br (M.L.B. Martinez).

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