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# Structural Health Monitoring Of Power Line Using Bragg Sensor

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**Abstract.** The process of establishing a damage detection and characterization method for engineering structures is known as structural health monitoring. SHM entails monitoring a system over time with the help of periodically sampled response data from a variety of sensors. Bragg reflector, which is a discrete spectrally reflecting carved in centre of optical fibre under the high intensity source is known as a fibre Bragg Grating sensor. Its purpose is to investigate how the Fibre Bragg Grating Sensor (FBGS) monitors the temperature on power lines. The main aim is to change the pressure, strain and temperature data through FBGS, BOTDR (Brillouin Optical Time Domain Reflectometry) makes use of spontaneous Brillouin scattering, which has a low backscatter power level. To identify the weak reflection signal, a sophisticated detecting mechanism must be applied. We demonstrated that utilizing Optisystem, we can module the optical spectrum, allowing us to monitor the whole FBG.

**Keywords:** Fiber Bragg Grating Sensor, Fiber Optic Temperature Sensor, Brillouin Optical Time Domain Reflect meter, Optical Measurements, Optisystem software.

## I. INTRODUCTION

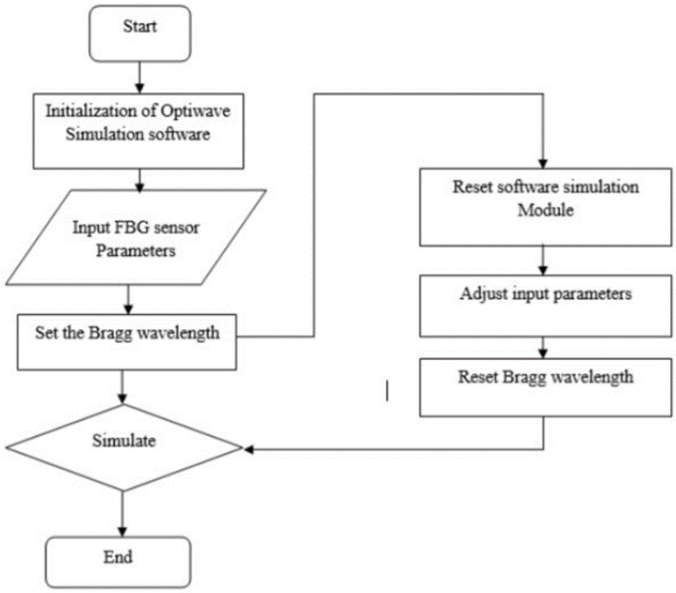
Power has driven practically every aspect of human life in the contemporary era. In the twenty-first century, it is widely accepted that having power is insufficient; instead, a steady, stable, and sustainable power supply is required [1][2]. It is no longer feasible to rely on existing infrastructure, as there is a constant need to innovate and adapt to the population's ever- increasing demands. The backbone of both economic and technical advancement is electricity.it has also undergone rapid transition as an industry in developing countries. However, these modifications are perceived as ineffective since the infrastructure is either not advancing at the same rate as the population's expectations or because the infrastructure's state is weakened by its age of installation. This indicates that failure is looming, since it is unable to handle the weight of prior centuries [3-5].

The risk of overusing transmission lines above their design capacity rises as energy demand rises as a result of increased population and economic activity. The progress of optical fibre sensing technology has become critical for temperature monitoring on power lines in this regard [6-8]. The optical fibre sensor looks to be more dependable and accurate than conventional methods since it is free from electromagnetic interference, mechanical vibrations and electrical noise, and functions best in harsh environments. The Fibre Bragging Sensor's temperature response is proved through theoretical study and software modelling. Electrical sensors have been employed as a common technique to measure physical and mechanical phenomena for the past 10 years [9][10].

Fibre optical sensors, which use light instead of electricity and fibre optical standards instead of copper lines, offer a good answer to these problems. Innovations in the disciplines of optoelectronic &fibre optics have significantly decreased the rate of optical components, also enhancing quality over last 20 years [11]. The optical fibre sensor technology is a direct outgrowth of revolutionstaken place in optoelectronic and fibre optic communication industries. The main components of a generic optical fibre sensor are a light source, optical fibre and a detection system. In a fully distributed fibre optic sensing system information from everywhere along the fibre is accessible. Entire optic fibre used as sensing element and signal transmission medium [12].

Optical Time Domain Reflectometry, or scattering, is a typical basis for distributed sensing systems. The scattered light is highly sensitive to the measured. Mainly scattering of light is classified into Raleigh, Mie (both linear scattering), Brillouin and Raman (both nonlinear scattering) scattering. Of these scattering techniques, studies reveal that Brillouin scattering is temperature sensitive i.e., this scattering is due to the thermally generated acoustic vibrations produced by the transmission of light beam along the optic fibre. In this scattering mechanism, the incident photon produces an acoustic frequency phonon as well as a scattered photon. This results in a frequency shift that is sensitive to temperature changes (highest in the backward direction and zero in the forward direction) [13].

Brillouin scattering is of two type's spontaneous and stimulated Brillouin scattering. Spontaneous Brillouin scattering occurs with low requirement of input power and stimulated. Brillouin scattering occurs above a particular threshold power. Stimulated Brillouin scattering limits the sensing distance of the sensor. Proper design of the SBS threshold point leads to the simulation of better responding distributed temperature sensor. The distributed temperature sensing is effective technique for measuring temperature in structural health monitoring, oil and gas well monitoring, cryostat temperature sensing, building detection and so on.




The most typical strategy in FBG sensors is to monitor the shift in the Bragg wavelength of the FBG under test. where changes in measurement strength are changed into grating structure modulation. The core index varies periodically along the axis when UV irradiates a fibre grating, generating fluctuations in its spectrum properties. The rest of the paper isorganized as follows, briefly presents modelling and analysis of power line and then introduces Fiber Optic Sensing Based on Brillouin Scattering. Finally the results and discussions were displayed.

## II.MODELLING AND ANALSIS OF POWER LINE

The FBG sensor was demonstrated and simulated using Optisystem simulation tool to show its operation [14][15]. When the temperature changes, the fibre grating works as a temperature sensor. The grating period and refractive index of the grating both vary. As a result, when the temperature of the grating device changes, the response of the grating device changes. These block diagram represents the modelling of fibrebragg grating sensor in Optisystem. The flowchart for Optiwave simulation software is given below Fig 1.

The Optisystem layout settings are presented in Fig 2. As a result, the components employed in the simulations are explained. Continuous Laser Diode is used to generate optical signals with a central wavelength of 1550nm and a spectrum range of 1530nm to 1570nm. It has a -130dbm input power and a 193.1 THz operating frequency, respectively. Because of its lower dispersion, faster data rate, and ability to operate over long distances, the optical fibre utilized here is a single mode optical fibre. The signal transmission length in the above-mentioned model was 50 kilometers. The attenuation coefficient of the fibre is 0.2db/km. FBG has been utilized as a dispersion compensator to compensate for variations in grating period in signal spectrums. The above-mentioned model's length is 10mm. At the end of each component, an optical spectrum analyzer is utilized to assess signal spectrum strength. WDM Sensor Interrogator is used to monitor the operation of the fibrebragg sensor as well as display the output and reflected signal spectra. FBGS can be made with a variety of Bragg wavelengths, allowing individual FBGS to reflect different wavelengths of light.

**Figure 1:** Flowchart of Optiwave simulation software

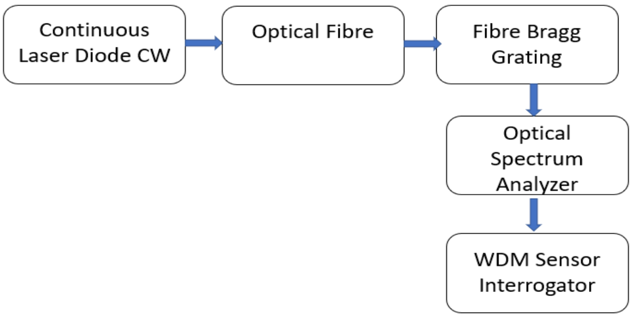



**Figure 2:** Designed Model in optisystem

## III.BRILLOUIN SCATTERING BASED FIBER OPTIC SENSING

In structural health monitoring, distributed temperature sensing is an excellent technology for assessing temperature. A distributed fibre optic sensor based on Brillouin scattering offers the benefit of correctly monitoring temperature. Stimulated Brillouin scattering (SBS) threshold parameters are polarization factor, Brillouin gain coefficient, effective core area, effective length of fibre. By adjusting these parameters accurately SBS suppression by 7.5dB to attain maximum sensing distance of up to 70km is possible. In Brillouin scattering based distributed temperature sensor the Brillouin frequency shift is temperature dependent. Thus, BOTDR sensor was simulated using Optisystem software. The basic block diagram of BOTDR sensor is shown below FIG 3. The block diagram mainly consists of a CW laser source, modulator, bidirectional optical fibre and a receiver.

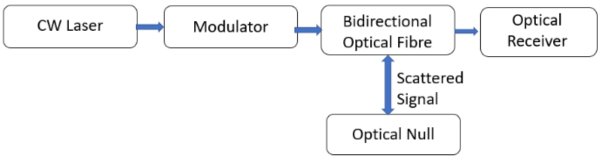



**Figure 3**: BOTDR sensor simulation layouts

The light coming from the laser source is modulated by intensity modulation then it is coupled into the bidirectional optical fibre. In bidirectional optical fibre collection of scattered signals is possible. The receiver will detect the Brillouin back scattered signal. Optical null is used to terminate the connection. To create a pulsed source, a modulator is linked to the laser source. The modulator is connected to a pulse generator called the "NRZ Pulse Generator," which is connected to a "Pseudo-Random Bit Sequence Generator". The pulsed light is launched into a 70-kilometer-long bidirectional optical fibre known as

"Bidirectional Optical Fibre". The backscattered power is measured with an optical power metre. By adjusting SBS suppression factors Brillouin threshold power up to 7.5dBm can be obtained for sensing distance 70Km. fabrication of optical fibre through vapor phase axial deposition method helps to meet all these conditions as shown in Fig 4. These proposed improvements reduce the cost of fabricating the optimized fibre. Thus, the cost of regenerator can be saved by the threshold power increment.

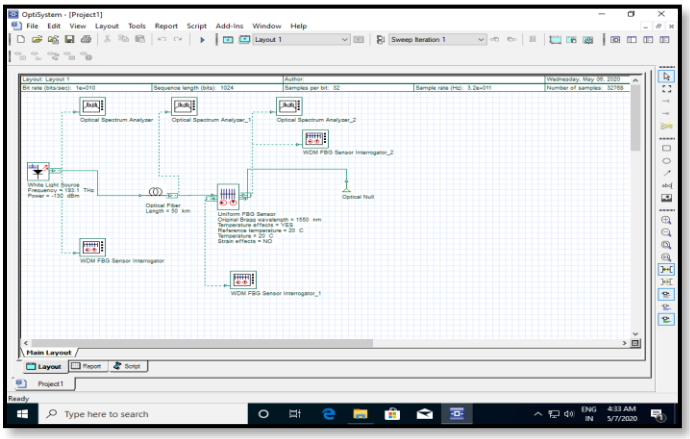



**Figure 4**: Designed model of simulated system with Optisystem.

## IV RESULTS AND DISCUSSION

Figure 5 and Fig 6 show the output transmitted spectrum, with dips indicating reflected wavelengths as a result of temperature shift from reference temperature. Basic elements used for this simulation is shown in figure 4. The goal of this paper was to look at how a fiberbragg grating sensor works when it comes to sensing the temperature on a power line. For theoretical and modelling purposes, a temperature range of between degrees centigrade and 160 degrees centigrade was used. The reference temperature is 20 degrees Celsius, while the maximum temperature allowed on the ACSR overhead power line is 80 degrees Celsius.

The temperature range was taken from degree centigrade to 160 degree centigrade. The reference temperature is 20 degrees Celsius, while the maximum allowable temperature for ACSR overhead power lines is 80 degrees Celsius. 40 Bragg reflectors. The temperature range was chosen to be between degrees centigrade and 160 degrees centigrade for theoretical and simulation purposes. The reference temperature is 20 degrees Celsius, while the maximum allowable temperature for ACSR overhead power lines is 80 degrees Celsius, 140 degrees Celsius, and 160 degrees Celsius, which are responsible for the corresponding Bragg wavelength changes.

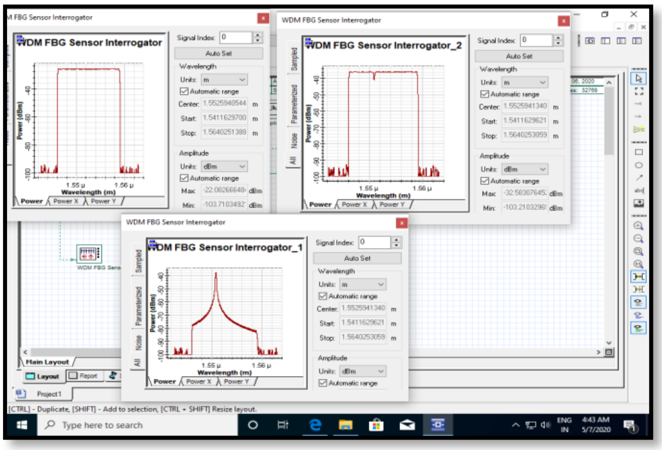


**Figure 5**: Shift in Bragg wavelength for temperatures from 20-80 and Transmissivity for temperatures 20C -80C

The temperature range was taken from degree centigrade to 160 degrees centigrade. The reference temperature is 20 degrees Celsius, while the maximum allowable temperature for ACSR overhead power lines is 80 degrees Celsius. 40 Bragg reflectors. The temperature range was chosen to be between degrees centigrade and 160 degrees centigrade for theoretical and simulation purposes. The reference temperature is 20 degrees Celsius, while the maximum allowable temperature for ACSR overhead power lines is 80 degrees Celsius, 140 degrees Celsius, and 160 degrees Celsius, which are responsible for the corresponding Bragg wavelength changes.

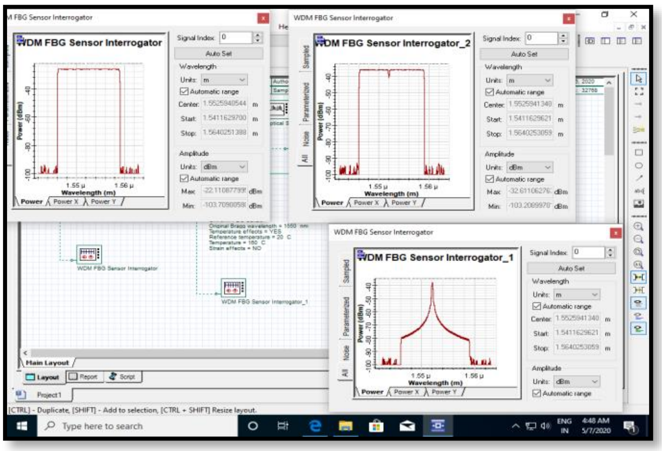


**Figure 6**: Shift in Bragg wavelength for temperatures from 100-160 and Transmissivity for temperature 100C-160C

**V.Measurement of Temperature, Strain and Pressure**

FBGS is the most important sensing component since it allows us to detect a wide range of factors, including temperature, rotation, vibration, and pressure as shown in Fig 7. To get real terms, we add a connector with a 0.2dB/Km insertion loss.

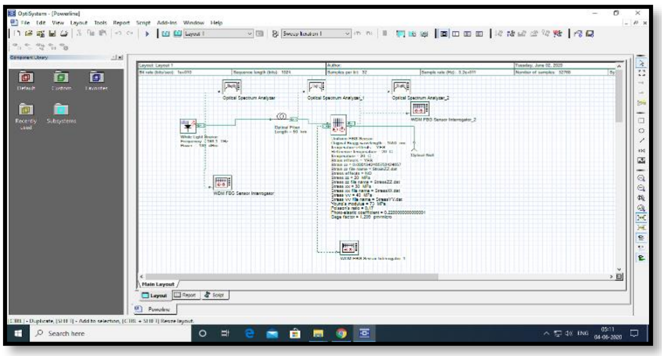


**Figure 7**: Expanded View of FBGS simulation using Optisystem

The reflected Bragg wavelength signal has the lowest power, according to measurements obtained with an optical power metre. The wavelength shift of a homogeneous FBG has a reasonably linear optical power response. The elongation of the fibre grating induced by the optical displacement is proportional to the wavelength shift. We can determine the wavelength shift from the optical power of distinct signals, and then apply this processing method to generate stable vibration / temperature / pressure measurements. FBGS can monitor pressure repeating to temperature and strain sensitivities due to its strong linearity, as demonstrated in Fig 8.

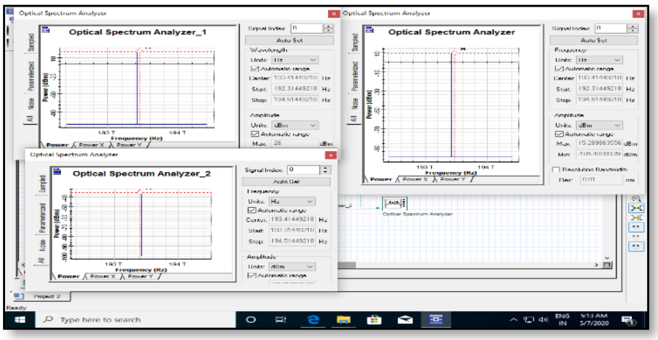



**Figure 8**: Output response of the Optical Power Spectrum of Pump Signal, Optical Power Spectrum of Fiber Bragg Grating Signal and the Optical Power Spectrum of Reflected Fiber Bragg Grating

## VI. Brillouin Scattering Simulation

The distributed temperature sensing is effective technique for measuring temperature in SHM. Brillouin scattering based distributed fibre optic sensor has an advantage of measuring temperature accurately. Stimulated Brillouin scattering (SBS) threshold parameters are polarization factor, effective core area, Brillouin gain coefficient, effective length of fibre. By adjusting these parameters accurately SBS suppression by 7.5dB to attain maximum sensing distance of up to 70km is possible. In Brillouin scattering based distributed temperature sensor the Brillouin frequency shift is temperature dependent. Thus, an effective Brillouin optical time domain reflectometry (BOTDR) sensor was simulated using Optisystem software shown in Fig 9 and Fig 10.

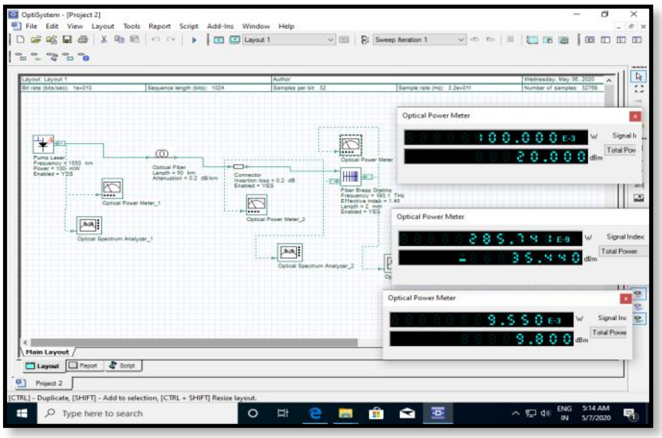



**Figure 9**: Response in Optical power meter

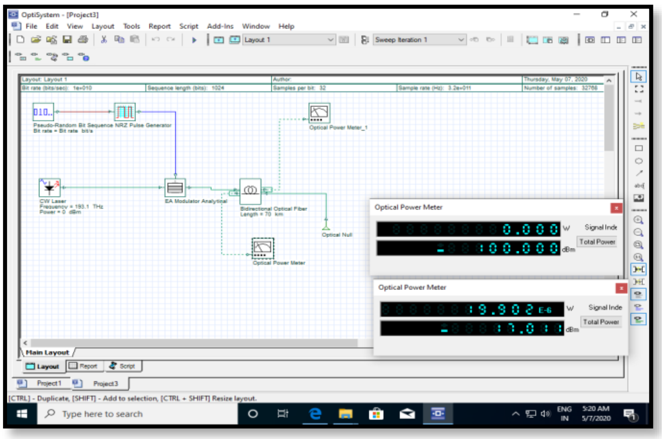



**Figure 10**: BOTDR sensor simulation layouts

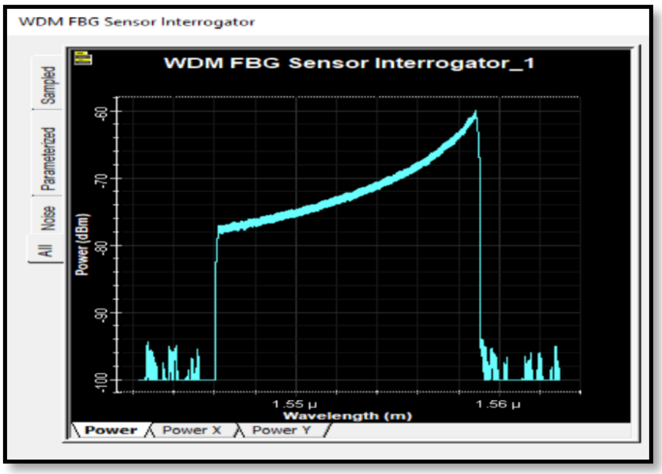


**Figure 11**: Stress variations on powerline

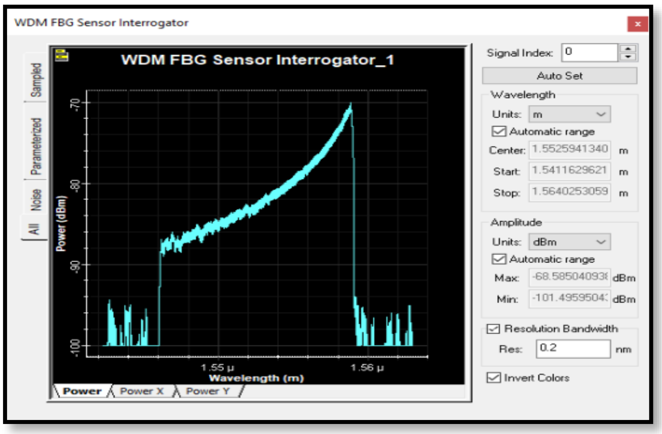



**Figure 12**: Strain variations on power line

The Optisystem simulation programme was used to simulate this project. On the software's interface, a transmission system was created to demonstrate the functioning operation of a Fiber Bragg Grating when used to monitor temperature on the power line. The length of the fibre that was used Is 50 kilometres, which is the distance a transmission is exposed to rising temperatures from the outside due to air conditions, sun heating, or the joule effect caused by current travelling through the powerline. The stress and strain variations on powerline is shown in Fig 11 and Fig 12.

## CONCLUSION

The purpose of this paper was to examine the workings of a Fiber Bragg Grating sensor in measuring the temperature on a power line. Temperature range for modelling reasons was set to 20 degrees Celsius to 160 degrees Celsius. The reference temperature is 20 degrees Celsius, while the ACSR overhead power line's maximum permitted temperature is 80 degrees Celsius. To understand the relationship between these parameters, theoretical calculations were performed to identify the relationship between temperature rise, grating period, thermo-optic coefficient, and wavelength. The linearity between temperature change and Bragg wavelength shift was demonstrated in this paper. Brillouin Optical Time Domain Reflectometry (BOTDR) takes advantage of spontaneous Brillouin scattering with a low backscatter power level. To identify the weak reflection signal, a sophisticated detecting mechanism must be applied. As a result, suppressing Stimulated Brillouin Scattering becomes necessary and crucial. Stimulated Brillouin scattering is affected by a number of variables. Brillouin threshold power of up to 7.5dBm can be obtained for sensing distances of 70km by changing the SBS suppression factors. All of these parameters can be addressed by fabricating optical fibre using the vapour phase axial deposition approach. The cost of constructing the optimised fibre will be reduced as a result of these proposed changes. Thus, the cost of regenerator can be saved by the threshold power increment.

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