

Application of Fiber Optic Sensors in Wind Power Plant(WPP)

Ashok kumar A. Parmar¹, Ankit P. Shah², P. G. Pithadiya³, P. S. Chaudhari⁴

Lecturer, Electrical Engineering Department, B. & B. Institute of Technology, V.V.Nagar, India^{1,2,4}

Lecturer, Mechanical Engineering Department, B. & B. Institute of Technology, V.V.Nagar, India³

Abstract: Wind Power is one of the fast growing renewable energy source in India and the world. India, in particular, is among top five countries in wind power generation with present Installed capacity of over 18000 MW and more. As demand grows, generation capacity in modern wind turbine goes in Megawatt scale. A modern big turbine requires sensing and controlling of various parameters like temperatures of moving parts. Fibre Optics with its electrical isolation and being light weight characteristics can have great potential to sense control parameters of wind turbine and to communicate to the control unit. Fibre optic sensors are precise and reliable under electrical hazardous environment of wind energy. Fibre Optic Technology has proved itself in present generation Communication system. The same high speed long, distance communication Networking can apply in onshore and offshore wind farm. The lower attenuation, greater bandwidth compared to copper cables and above all, immunity to high electric power, fibre optics are proving its significant role in automation of wind turbines. The signals that carry optical fibre provide reliable information for health monitoring and controls of wind turbines.

Keywords: Fibre Optic sensors, Fibre optics communications, Renewable energy, Wind power Plant(WPP), Wind energy converter (WEC), Control and Monitoring

I. INTRODUCTION

Wind energy has recently become a popular Renewable energy and energy efficient technologies have been attracting much attention in recent years due to the soaring energy crisis and environmental problems associated with the depletion of natural resources that are harmful to the earth. A wind turbine defined as a rotating machine which converts kinetic energy extracted from the wind through the rotating blades of wind turbine to mechanical energy. If this mechanical energy is converted to electricity through induction generator, the machine is called the wind turbine or wind energy converter (WEC).

Most modern wind power plants (WPP) have intelligent features to monitor and control the subsystems like rotor, gearbox, generators and yaw drive to accommodate varying wind conditions[1]. There are more than 100 parameters that are to be monitor or set in modern wind turbines. Fibre optic and other sensors monitor the condition and strength of the turbine's parts to avoid run-to-failure. These papers describe the principles and applications of fibre optic sensors in present generation megawatt wind turbine to monitor and control of such parameters.

In this paper section II addresses the principle of fiber optic in solar power plant and discusses the components and advantages of fiber optic system in solar power plant. The section III is related to the application of fiber optic sensors used in solar power plant. The section IV describes the application of fibre optics data link in a solar power plant and its networking to interconnect solar panels for communication and control in a solar farm. It also describes the application of fibre optics in substation automation in which fiber optic components are

commonly used to control a high voltage and current switching device with reliable control and feedback signals. The section V serves as a conclusion of the paper and discusses the importance of fiber optics in integration of solar power plants with the grid.

II. NEED OF FIBRE OPTIC SENSORS IN WIND POWER PLANTS

Latest wind turbines consist of six major components this include the rotor, nacelle, tower, gearbox, generator and balance of the system. The rotor is connected to the blades through a hub. The rotor blade then extracts kinetic energy from the wind and converts into mechanical energy, the hub supports the blades. Modern wind turbines also have a pitch mechanism that controls and changes the angle of the blade depending on the speed of wind and the rotation speed as desired. The enclosure at the top of the tower is nacelle which is the main structure and contains major components like the turbine generation, electronic control system and interface to connect with the power grid. The modern turbine also has an online condition monitoring system for continuous monitoring of dynamic behaviour of WEC[1].

Fibre optics sensors becomes a preferred choice in megawatt rated wind turbine as it offers much higher voltage and current isolation properties compared to other similar counterparts. Optical fibre is used as a sensing element to monitor and control various physical parameters of the turbine. Applications within the turbine nacelle using fibre optic links insure that the turbine has a high reliability[12].

As shown in figure 1, some of the main fibre optic sensor application area in wind turbine includes:

- Vibration of generators
- Temperature of Breakers
- Temperature of gear box
- Pitch and yaw control systems
- Strain of blades
- Wind pressure
- Stability of rotor and tower
- Ice and Moisture control

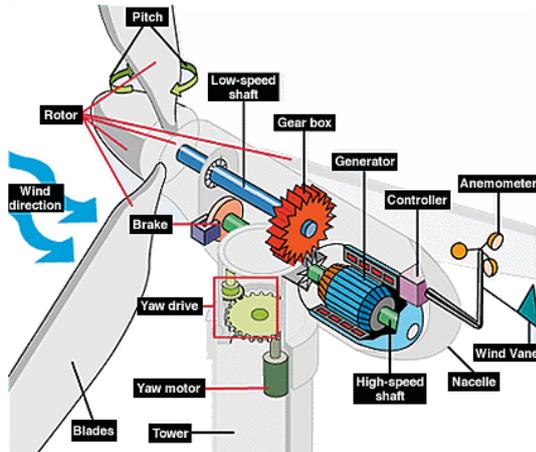


Fig. 1. Fibre optics locations in wind turbine nacelle
Source: www.my-ftm.com/0805/080521.asp

III. FIBRE OPTIC SENSOR TYPES IN WPP[1],[10][11]

Fibre optics overcomes the common issues to fulfil the need for speed in real-time monitoring, while providing a more stable conductor and better data security than copper components. Optical fibres are used in wind power system as:

- Monitor and control
- Sensors for sensing

TABLE I: OPTICAL FIBRE SENSOR APPLICATION IN WIND TURBINE [11]

Name of fibre optic sensor	Description of Sensor type	Application in wind turbine
Temperature	Intensity modulated intrinsic optical fibre sensor, Fibre Bragg Grating sensor	Monitor temperatures at all bearings, shafts, gearbox oil, generators, yaw drive and brakes
Vibration	Intensity modulated extrinsic optical fibre sensor	Monitor vibration of tower, generator
Pressure	Fibre optic Polarization modulated sensor	Monitor wind pressure and wind flow
Strain	Fibre Bragg Grating or Rayleigh Scattering sensor	Monitor blade strain for being damage, used in large turbine blades
Displacement	Intensity modulated extrinsic optical fibre sensor	Monitor tip deflection of blades to prevent blades hitting the tower
Moisture, ice	Intensity modulated intrinsic optical fibre sensor	To prevent wind turbine degradation
Rotation	Fibre Optic gyroscope, interferometric type	Monitor pitch angle of each rotor blades, yaw angle of rotor

The basic principle involving in Fibre Optic sensors is the change in light wave characteristics in the fibre waveguide by the parameter that required to be sensed or monitor. If light wave characteristics altered inside of optical fibre then it is called intrinsic sensor and if fibre is used as

modulated light carrier probe, it is referred to as extrinsic sensor.

There are basically four sensing mechanism in fibre optic sensors:

- Intensity Modulated Sensors
- Phase Modulated Sensors
- Polarisation Modulated sensors
- Wavelength/ Frequency Modulated Sensors

By the way of measuring one of these variations, optical fibre sensors are suitable to measure and monitor temperature at various parts of wind turbine, strain and pressure of wind blades etc. Some of the Optical fibre sensors used in modern wind turbines are listed in table I. There are several techniques to vary and measure sensing parameters using Optical fibre as a sensing element. Some of the principles are explained as following. The actual performance and installation complexity of these sensors in wind power generation conditions are to be researched and verified.

A. Fibre Optic Strain and Temperature Sensor:

The Fibre Bragg Grating (FBG) is used to sense strain of the blades of large wind turbines and temperatures at various heat generating locations of the turbine.

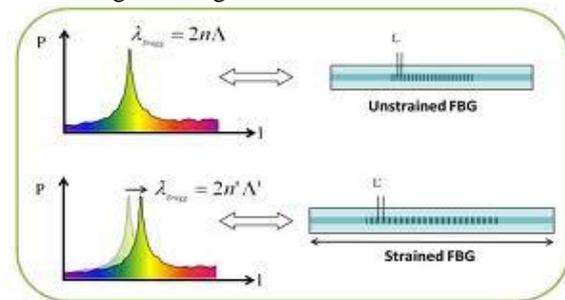


Fig.2 : Fibre Bragg Grating principle[11]
Source: <http://www.fbgs.com/technology/fbg-principle>

(a) Strain Sensor

Three to four FBG strain gauges is embedded during manufacturing of each turbine blade. The periodic changes in refractive index (Grating) of Core of the Optical fibre is obtain to make is sensing element. The incident light is reflected from this grating structure which is observed on Optical Spectrum Analyser (OSA). Strain in the fibre alters the grating spacing, hence the reflected wavelength. The change in reflected wavelength (Bragg wavelength) corresponds to amount of strain on the fibre. It has sensitivity of 1.2 picometer change in wavelength per micro strain of the blade.



Fig. 3: Fibre Bragg Grating module[11]
Source: <http://www.o-eland.com>

(b) Temperature Sensor

The similar Fibre Bragg Grating Sensor is used to measure temperatures at various parts of the wind turbine. The sensing FBG can be placed in the closed proximity of heating component of the wind turbine. The refractive index of the silica glass fibre changes with temperature. As the effect of temperature the Bragg wavelength shift which is measurable. The sensitivity is 10 picometer wavelength shift per °C of heating element.

B. Fibre Optic Pressure and Vibration Sensor:

This sensor can be mounted on the tower to monitor wind pressure and wind flow. It also can sense vibrations of the generator and nacelle. Bending the optical fibre at its dimension level causes output power to decrease, since some amount of light intensity radiated from core at bending location. The amount of power reduction depends on the bending radius of the fibre.

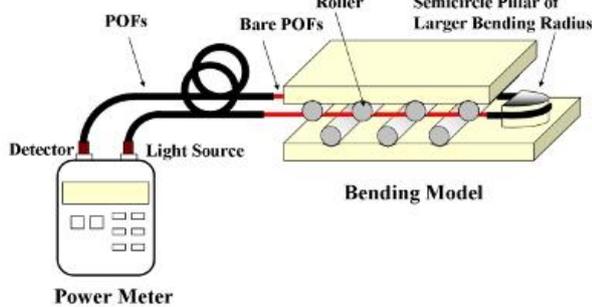


Fig. 4: Fibre optic Microbending Sensor [2][11]

Source: <http://www.mdpi.com/1424-8220/10/11/10198>

A suitable bending mechanism, as shown in figure 2.4, can be designed to obtain bending in fibre because of the pressure or vibration

C. Fibre Optic Rotation Sensor :

Pitching angle of blades and Yaw angle of rotor can be measured with Fibre Optic Gyroscope. Fibre optic gyroscope can be placed on bearings of each pitch drive to sense angular variations of blades in pitch control wind turbine. This sensor also can be placed on yaw drive of rotor to maintain rotor towards wind direction.

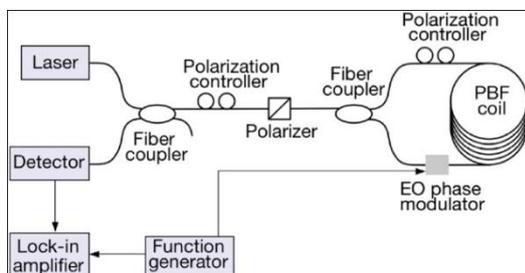


Fig. 5: Fibre optic Gyroscope[2],[11]

Source: <https://spie.org/x39028.xml>

Fibre optic gyroscopes are of two types: polarization modulated or phase modulated. The basic principle involves in the polarization modulated gyroscope (figure 2.5) is when bundle of is rotated on its central axis, the state of polarization of light wave passing through it changes. The amount of measurable change in polarization

depends of angular speed of fibre bundle. In phase modulated interferometric Gyroscope (Sagnac Interferometer) the change in the phase of input light wave entered into fibre bundle and output light wave determines the bundle rotation speed

D. Fibre Optic Displacement Sensor:

This sensor can be mounted on tower of the wind turbine (figure 2.6) to monitor tip deflection of blades to prevent blades hitting the tower.

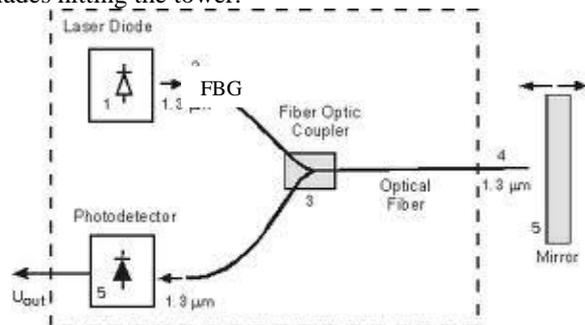


Fig. 6: Fibre optic displacement sensor schematic [2]

Source: <http://physics-animations.com/sensors/English/interf.htm>

IV. FIBRE OPTIC SENSOR ADVANTAGES IN WPP

Compared to Electronic counterparts, Fibre Optic sensors are having greater advantages in megawatt scale wind turbines. Some of the main benefits of Fibre Optic sensors are[12]:

- Reliable, since dielectric optical fibres are immune to EM interference.
- Precise, since small variations in physical parameter can lead to measurable changes in intensity and phase, in particular, of light waves.
- Having long range of operation.
- Small in size and light weight
- Optical fibre Bragg grating sensors- non disruptive to the laminate
- Absolute strain measurement with no drift or debonding
- Installed during blade build or retrofitted to operational machines
- Sensor quantises, locations and spacing can be custom designed to suit exact turbine dimensions and sensing requirements.

Because of these advantages, use of fiber optics makes it possible to install sensors distributed over the blade, which significantly increases the information content. This is possible mainly because of the multiplex capability of signal acquisition and routing in fiber optic lines. Hybrid solutions can also be created with a suitable combination of fiber-optical and electrical sensors. These systems are able to record changes very rapidly.

V. CONCLUSION

In this paper we have technically reviewed that optical fibres are having great potential in wind power plants. Its galvanic isolation characteristics can make them popular

in present day megawatt wind turbines. Older wind turbines can also be modernized using fibre optic technology for reliable, efficient and stable performance of various subsystems within wind turbine which Offer completes monitoring solutions to the wind industry either for pitch control or Structural Health Monitoring (SHM) of the blade structures. In future advance signal processing and fibre optic network technology will improve the precision and cost of fibre optic technology embedded in high power wind turbines. [12].

REFERENCES

- [1]. Joshua Earnest &Wizelius, Tore – ‘Wind Power Plants and Project Development’: PHI Learning Private Limites, India pp.61 – 142; 2011
- [2]. Available:<http://powerelectronics.com> retrieved on 9th December 2013
- [3]. Available:<http://rtcmagazine.com> retrieved on 9th December 2013
- [4]. Available:http://www.fibreopticlink.com/Industry_Solutions/Wind_Energy.html
- [5]. Available:<http://www.windpowerengineering.com/design/materials/molex-says-think-fibre-optics-for-wind-turbine-monitoring/> retrieved on 9th December 2013
- [6]. Available:<http://www.greentechmedia.com/articles/read/wind-turbines-get-sensitive-retrieved> on 11th December 2013
- [7]. Available:www.specialtyphotonics.com retrieved on 10th December 2013
- [8]. Available:www.avagotech.com retrieved on 9th December 2013
- [9]. Available:http://iats09.karabuk.edu.tr/press/pro/02_KeynoteAddress_s.pdf retrieved on 9th December 2013
- [10]. Available:http://shodhganga.inflibnet.ac.in/bitstream/10603/1966/6/06_chapter%201.pdf retrieved on 9th December 2013
- [11]. Available:http://www.sem.org/pdf/fibre_optic_sensor_technology.pdf retrieved on 9th December 2013
- [12]. Available:<http://www.hbm.com/en/menu/tips-tricks/experimental-stress-analysis/fiber-optical-sensors-for-condition-monitoring/>

BIOGRAPHIES



I, Ashokkumar A. Parmar¹, is born in Somnath, Gujarat, India, in 1977. I received the B.E. degree in electrical engineering from the M. S. University of Baroda, Vadodara, India, in 1999, and the M.E. M. S. University of Baroda, Vadodara, India, 2000. Presently I am working as a senior lecture in Department of Electrical Engineering at Bhailalbhai & Bhikhabhai Institute of Technology since 2002. I am Life Member of the Indian Society for Technical Education (ISTE), Member of the Institution of Engineers (India), and International Association of Engineers (IAENG) (International). My current research interests include Artificial Intelligence and application to electrical engineering, Distributed generation and renewable energy system, Power markets and Power system Economics.



I, Ankit P. Shah, was born in Ahmedabad, Gujarat, India in 1979. I completed B.E. in Electrical Engineering from the Gujarat University, Ahmedabad, India in the year 2000 and the M.Tech. in Electrical Engineering from IIT Bombay, Mumbai, India in the year 2008. Presently I am working as a senior lecturer in Department of Electrical Engineering at Bhailalbhai & Bhikhabhai Institute of Technology since August 2002. I am Life Member of the Indian Society for Technical

Education (ISTE), Member of the Institution of Engineers (India), and Member of International Association of Engineers (IAENG). My current research interests include modeling and control of electrical machines, power electronics and renewable energy systems.



I, Pareshkumar G. Pithadiya³, was born in Shivrajgadh, Gujarat, India, in 1975. I received the B.E. degree in Mechanical engineering from the M. S. University of Baroda, Vadodara, India, in 1996, and the M.E. M. S. University of Baroda, Vadodara, India, 2000. Presently I am working as a senior lecture in Department of Mechanical Engineering at Bhailalbhai & Bhikhabhai Institute of Technology since 2002. I am Life Member of the Indian Society for Technical Education (ISTE). My current research interests include Thermal engineering, Heat and Mass Transfer, renewable energy systems.



I, Pareshkumar S. Chadhuri⁴, was born in Gujarat, India in 1982. I completed B.E. in Electrical Engineering from the H.N. Gujarat University, Modasa-Gujarat, India in the year 2004 and the M.Tech. in Electrical Engineering from Gujarat Technological University, Ahmedabad-Gujarat, India in the year 2011. Presently I am working as a senior lecturer in Department of Electrical Engineering at Bhailalbhai & Bhikhabhai Institute of Technology since November 2005. I am Life Member of the Indian Society for Technical Education (ISTE), Member of the Institution of Engineers (India), and Member of International Association of Engineers (IAENG). My current research interests include modeling and control of electrical machines, power electronics and renewable energy systems.