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Fiber Optic Communication in Wind Power Plant (WPP)

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Abstract: Wind Energy constitutes 4% of the total electricity produced in the world and is a very significant source of renewable energy. Power generation by wind turbine generators, or WTGs, is a proven green energy technology in both land and offshore environments. However, wind farms located either onshore or offshore are often in remote and not easily accessible locations. Additionally, their height above ground can pose unique maintenance, repair and lightning strike challenges that must be addressed to make wind power renewable energy reliable and economical. The right data and communication cables are very important in wind farms as the farms are usually quite large in area and very often, the environment is quite harsh in such locations. Hence it is necessary to use power transmission cables that are resistant to such conditions, and able to transmit power over long distances with the required efficiency. The two main options that are chosen for transmission cables include Bus-Ethernet and Fibre Optic Cables. Owing to several important reasons, the use of Fibre Optic Cables is highly preferred as compared to the former. Fiber optics (FO) technology is probably best known for use in high-speed, high-bandwidth telecommunication applications. But today fiber optics data and control links have replaced copper links in wind turbines and farms making them a critical part of a wind farm operator's solutions for minimizing costly downtime and service interruption. Optical fibre network provides real-time data capture to monitor wind turbine uptime, performance and power output – even from remote locations. This data is used to track efficiency and trends, plan maintenance schedules, report the power produced and predictive information to the Independent System Operator critical to "Smart Grid" technology

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

I. INTRODUCTION

With the aid of cutting-edge technology, the power of wind can be easily channelized for energy production and subsequent generation of electricity. 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 21000 MW and more [1]**.** 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. Fiber optic technology is the most suitable and in some cases the only acceptable technology in high electrical noise environments for electrical generator/turbine control, power conversion and wind farm wide-area communications. The characteristics and reliability benefits of FO components receivers, transmitters, transceivers and cable are applicable in wind farms and wind turbines, as well as overall wind farm and wind park operation. 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 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.

In this paper section II addresses the need of fibre optic sensors in wind power plant .The section III& IV is related to fiber optic wind turbine control networking with technical specifications for wind power plant and wind farm. The section V describes the maintenance of optic fibre network for wind power generation. The section VI serves as a conclusion of the paper and discusses the importance of fiber optics communication in integration of wind power plants with the grid.

II. FIBRE OPTICS IN WIND POWER GENERATION[12],[14]

Most of the commercial wind turbines installed today are having high power rating in Mega Watt range. Sensors and data communication links are established to make these turbines fully automated in its functioning. Any data signals on copper wires (figure 1) routed next to these power lines are subject to induced noise This system is prone to electromagnetic interference and is not suitable for applications in wind turbine.

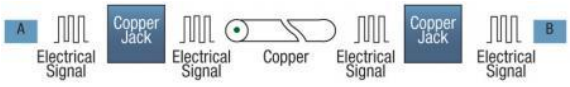

Fig. 1Typical copper wire communication system
Source:http://www.rtcmagazine.com/articles/view/101628

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Fibre optic systems are used for both electrical isolation purposes and data communications. Any data signals sent through fibre optic lines as shown in figure2 are not subject to such electromagnetic interference. The dielectric optical fibre is immune to electromagnetic interference and is suitable for reliable applications in wind turbine

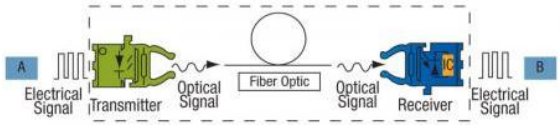

Fig. 2Typical optical fibre communication system
Source: http://www.rtcmagazine.com/articles/view/101628

Because of the galvanic isolation and low attenuation of optical fibre, wind turbine utilises fibre optics in two ways: as a communicating system between devices and as sensing element itself. Some of the key area in wind turbine and wind farms where fibre installations suitable are:[2]

- Power electronic gate driver for rectifiers and inverters
- Control and communication boards
- Turbine control units
- Condition monitoring systems
- Wind farm networking

A. Components of Fibre communication system:

Fibre optic system consists of optical, mechanical and electronics subsystems.

(a) Optical Fibre Cable:

Optical fibre is cylindrical waveguide (figure 3) to carry light signal from transmitter to receiver. It is made of transparent dielectric materials like glass and plastic to form core and cladding of optical fibre. This optical fibre is used as a medium to transfer communication and control data in wind power plant. The optical fibre can itself be made as a sensing element to monitor temperature, voltage, current at various stages of Nacelle and also to monitor the strain of blades.

Fig.3 Fibre optic cable.
Source: www.trades.indiamart.com

(b)Transmitter and Receiver:

As shown in figure 2 an optical transmitter consists of semiconductor light source to convert electrical signal onto corresponding intensity of light (LED or Laser Diode) and driver circuitry to drive light source. The receiver, at the other end of optical fibre, converts the received optical power back into electrical one. Semiconductor photodiode (PIN or APD photodiode) serves the purpose of conversion at receiver.

(c)Connectors and Couplers :

Optical fibre Connectors (figure 1.4) are precisely dimensioned mechanical device attached at both ends of fibre. This is to connect light signals into optical fibre from light source of the transmitter and deliver light signal from fibre to detector of receiver.

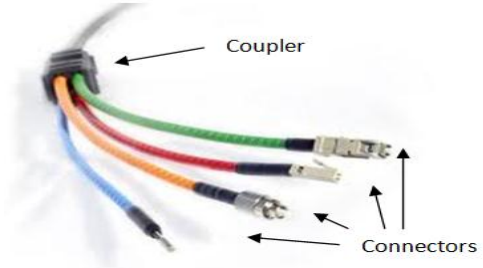

Fig. 4.Fibre Optic Connectors and Coupler.
Source:www.fibreoptic101blogspot.in

B. Specifications of Fibre communication system:

There are many choices among fibres, sources, detectors and connectors. Some of the specifications are listed below in TABLE- I*:*

III. FIBRE OPTIC WIND TURBINE CONTROL NETWORKING

The fibre optics is typically found in various systems within the wind turbine associated with displacement sensor, vibration sensor, ice sensors, temperature sensors, speed & wind direction laser sensors, and Fibre Bragg Grating sensors for monitoring strain on the blades etc. Outputs of these sensors are required to feed to controllers. Controllers transmit control signals to be sent to various sections of the wind turbine. One PLC controller is also placed at the bottom of tower to control wind turbine and electric substation. Any kind of duplex communication setup has to be established in this regards. Fibre optic communication data links became preferred choice, considering its electrical isolation characteristics.

TABLE I: SPECIFICATIONS OF DIFFERENT GLASS FIBRES FOR WIND POWER APPLICATION [11]
Source: http://ist.berkeley.edu/telecom/nso/pm-sd/standards/fibre-optic-cabling

Types of fibre	Source type and Operating wavelength	Core/ Cladding diameter in µm	Attenuation (dB/ KM)	Bandwidth (MHz*KM)	Remark
Multimode Glass fibre	LED, 850 nm	62.5/125	3.0	200	Ease to handle, suitable for communication within Nacelle, from nacelle to control unit at tower bottom.
Multimode Glass fibre	LED, 1300 nm	62.5/125	0.9	500	
Singlemode Glass fibre	LD, 1310 nm	9/125	0.35	More than 3000	Stable and precise Connectorization needed, suitable in wind farm networking
Singlemode Glass fibre	LD, 1550 nm	9/125	0.2	More than 3000	

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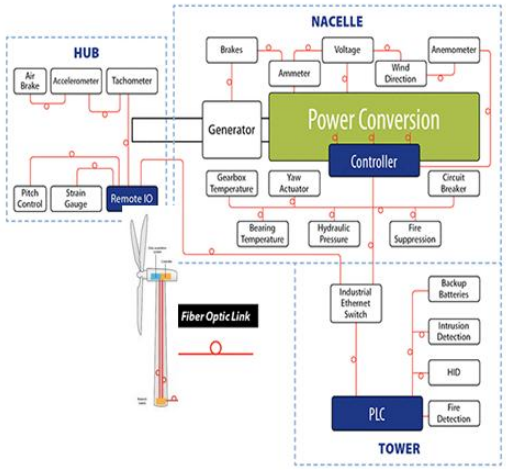

Fig.5. Fibre Optic Control Networking in a wind turbine. Source: http://www.firecomms.com/applications-renewable_energy.html

Fibre Optic Selections:
Since data rate in not the critical issue (Mega Bit Per Seconds, MBPS) within wind turbine and transmission distance of 100 meter or so, following could be the selection choice from fibre optic technology:

Optical fibre cable: Reinforced Multimode Glass Fibre Cable, 50/125 core-cladding ratio.

Light Source: Light Emitting Diode (LED)at operating λ = 1.3 µm

Light Detector: PIN photodiode

Signal conditioning::Hamming coded digital format.

IV. FIBRE OPTIC WIND FARM NETWORKING

Communication between wind turbine towers and master control unit is another major issue since wind farms typically span vast distances that may go on for few kilometres in the electrical hazardous environment. The issue is even more crucial in offshore wind farms where turbine spacing could go up to 5 km or more. Networking and Communications products used in these applications require industrial-grade durability in order to withstand such conditions. Given these circumstances, it is essential for wind farms to use only rugged and highly reliable communications and networking equipment that employ the use of fibre optics instead of Copper wire. Double shielded CAT6 Networking cable is the expensive alternative to fibre optic cable. Fibre optic cable has superior dielectric properties and is immune to EMI events and temperature extremes that could interfere with communication, monitoring and control of the wind farm and its control facility.

Fibre Optic Selections [4]
Data transmission over Single Mode Fibre (SMF) cable has to incorporate in the installation for high MBPS data over longer distance in a wind farm. Following could be the selection choice from fibre optic technology:

- Optical fibre cable (Onshore): 12 SMF ADSS Cable, 9/125 core-cladding ratio.
- Optical fibre cable (Offshore): 12 SMF Armoured Cable, 9/125 core-cladding ratio.
- Light Source: Laser Diode (LD) at operating λ = 1.3 µm
- Light Detector: InGaAs APD photodiode
- Signal conditioning: 5B6B NRZ digital format

Fig.6 shows a typical Fibre Optic wind farm Network. Fibre Optic installation could be underground or Aerial. Underground duct installation has benefits of being comfortable and space saving. There are several choices among commercially available fibre optic cables. Some of the main Fibre Optic Networking equipments (Cisco Inc. Company is pioneer in this regards) are:

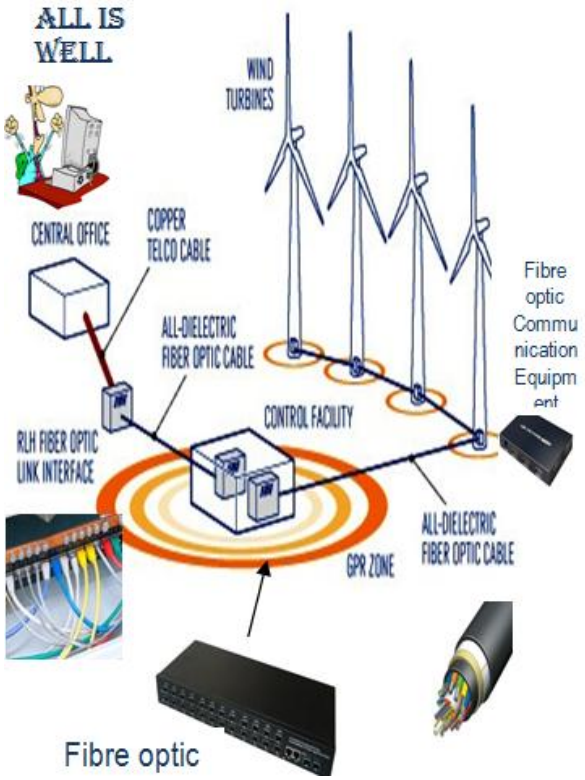

Fig.6 Typical Fibre Optic Network in Onshore Wind Farm Source: http://www.fibreopticlink.com/Industry_Solutions/Wind_Energy.html

- **Optical Switches**:Interconnect Multiple channels to communicate each other, used in controller at nacelle and at bottom of the wind turbine.
- **Optical Routers**:Manage data traffic by providing least path to data packets, used at Master Control Station.
- **Optical Repeaters**: Amplify and regenerate data, required in very large wind farm
- **Link Interfaces:**Interconnect different Physical layer Communication Protocol

V. FIBRE OPTIC SYSTEM MAINTENANCE

Fibre Optic Sensors are eyes and ears of the wind turbines. Any kind of malfunction in these Sensors and

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corresponding Fibre Optic Communication channel may lead to bigger damage in wind power generation systems.
There are two kind of maintenance for fibre optic system:

- Periodic Maintenance
- Breakdown Maintenance

The performance of fibre optic sensors decreases over the period of time due aging and environmental effects. Sensors installed at various parts of wind turbine have to be calibrated or replaced as specified by manufacturer for their optimum and reliable functioning. Light Sources like Laser diode, used in Data Communication Equipment loses its power output stability in the operating age of two years or so. The sensitivity of light detectors (APD in particular) deteriorates in the same manner. Light sources, detectors or corresponding communication equipment has to be replaced in the period of two years or as per manufacturer's specifications.

Optical Fibre Cables do have aging effect under the installation conditions. Its attenuation and mechanical strength characteristics decreases and are require replacing with new cable.

Fibre cables installed in turbines and in wind farm may break in excessive wind pressure conditions or accidentally. In this breakdown condition, small patch cable (inside turbine) is to be replaced and wind farm cable need to be spliced using Fusion Splicing Machine.

A. Fibre communication system maintenance Equipment:

The state-of-art-technology required similar level of maintenance. Following text describe some of the maintenance equipment that are needed in case of fault or failure.

(a) Optical Power meter:

It is a measuring instrument used to measure Power at the output of the fibre and power of the light source in Optical transmitters. Output of this meter (in watt and dBm unit) is displayed on LCD Panel. Optical Power Meter is calibrated at λ = 0.85µm, 1.3 µm, 1.55µm of operating wavelength.

Fibre can be connected through ST, FC or SMA input Connector

Fig.7Optical Power Meter Source:www.tradeindia.com

(b) Fusion splicing Machine:

It is used to splice the broken fibre together. Two ends of fibres are permanently joined with high alignment accuracy. Splice loss is as low as 0.1dB per splice. Screen is provided with each splice machine to observe alignment of fibre ends. Fusion splice machines are available with single fibre or multi fibre splicing facilities.

Fig.8 Fusion splicing MahineSource:www.tradeindia.com

(c) Optical Time Domain Reflectometer (OTDR):

This is one of the most important maintenance equipment of all and is looking like CRO. This measures Fibre Fault Location with high accuracy, Splice and Connector Losses, Attenuation in Optical Fibre and Fibre Installation Length. The fibre that is to be tested is connected to the input and resultant graph on the screen is analysed to measure these parameters.

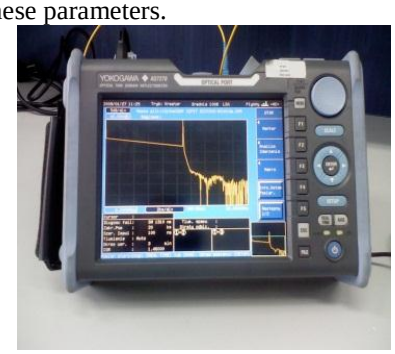

Fig.9Optic Time Domain ReflectoMeter
Source: http://en.wikipedia.org/wiki/Optical_time-domain_reflectometer

(d) Fibre Optic Tool Kit

The typical fibre optic tool kit comprises the followings in addition to commonly used mechanical and electrical tools:

Fig. 10 Fibre Tool Kit Source: http://bucarotechelp.com/networking/support/88102702.asp

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- Bare fibre cleaver
- Fibre cable striper
- Diamond scriber
- Index matching liquid
- Aramid yarn cutter
- Fibre cleaner

VI. CONCLUSION

Wind turbines are one of the most highly automated pieces of industrial equipment. By sensing changes in the wind, turbines simultaneously change blade pitch, or rotate to change direction to capture the best air currents. To perform these movements with precision, turbine components are connected with hundreds of feet of data and communication cables. When faced with the challenge of deciding what cable types to choose, engineers often focus on two – fiber optic and Bus-Ethernet. [4]One benefit of fiber-optic cables is they solve data communications problems over long distances, making them an appealing option for many industries. To put "long distance" into wind-turbine perspective, the longest working fiber optic-transmission line is approximately 560 ft.The cable's signals also withstand magnetic fields that change with electric currents. Fiber-optic cables can transmit data almost noise free and at high bandwidths. A drawback, however, to fiber optic cables is that their small size makes them susceptible to damage or cutting during installation or construction activities. Standard fiber-opticcables used in infrastructure applications are extruded with a thin polyvinylchloride (PVC) jacket or with a heavy PVC jacket when used in ground applications. Unfortunately, neither option meets industrial demands and requirements.

A Fibre Optics Communication and Load Monitoring Technology is also quite effective as far as safety and longevity of the wind turbine components are concerned. The ability to provide reproducible data, along with the high levels of safety and efficiency have made fibre optics very popular for wind farms. With this, there are several cable manufacturers that have emerged with the growing trend, but only a chosen few of them possess the technical brilliance that is needed for providing value for money.[10]

On one hand you have the highly critical and unavoidable nature of data communication on wind farms, and on the other hand you have the ever-persistent issue of cost. Balancing both at once often becomes a challenge, especially when highly resistant cables need to be procured in order to resist high temperatures and mechanical stress.

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BIOGRAPHIES

I,Ashokkumar A. Parmar[1],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 atBhailalbhai& 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.

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