Class 1
Item no. 951471.R0
2003-12-10

Fiber Cable Handling and Installation

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Fiber cable handling and installation requirements

1. Installation practices

Instructions in the data sheet from the producer of the cable should always be followed. The data sheet informs you about *minimum bending radius, tensile strength and temperature conditions, etc.*

Buried cables must be put in cable conduits. To ease repair or replacement in case of a breakdown it is recommended to pull the cables into tubes. It is a **requirement** that fiber cables must always be **at least 10 meters** longer than the actual distance between cable termination points. The reason for this excessive length is that in case of a break, you will be able to pull some of the surplus fiber out to the place where the fault occurred. This results in only having to make one splice on the cable instead of two (especially convenient if tubes are used). In the wind turbines, the excessive length is also required to ensure that the fiber cable can be routed in a safe and correct manner from the bottom of the turbines to the turbine controller cabinet, and to ensure that there is enough cable for splicing and mounting of connectors.

The following is to be considered when selecting the fiber cable type:

- What type of fiber is needed (Single-Mode/Multi-Mode, depending on distance)?
- How many fibers are needed in each cable section?
- Indoor cable: demands regarding fire, smoke emission, halogen free cables, etc.?
- Outdoor cable: is moisture and rodent protection needed (glass or metal protection – metal protection is only recommended if required by local demands); will overhead cables be used (high tension, UV resistant, etc.)?
- *Loose buffer* cable types **must** be used for outdoor purposes and tight-buffered cable may be used for indoor purposes (patch cables).

In case of underground splicing, you must use closures that are environmentally sealed and are approved for underground use.

2. Labelling

All installed cables shall be labelled at both ends with an appropriate labelling system. Label lettering shall be clearly legible black lettering on a white or yellow background. In all practical instances, labels shall be oriented such that the label can be read without moving the cable to which the label is affixed.

Labelling shall be as follows:

---“WT1 – WT2” -------------------------/~/-----------------------“WT1-WT2”----

The text indicates “to – from” on each end (the ‘from’ indicates where the fiber comes from, and ‘to’ indicates where the fiber shall go to. The ‘to’ part is always placed at the end of the fiber.

3. Optical fiber cable types

The accepted fiber cable types for use in Vestas communication systems are listed below. All fiber equipment (switches, converters etc.) used by Vestas is operating at 1300 nm - except long-haul equipment that operates at 1550 nm.

Type of cable	Core Cladding diameter	Max. Attentuation	Min. Bandwidth (MM) Max. Dispersion (SM)	Switch power budget[1)]	Max. length[2)]
Multi-Mode[3)]	50/125 µm 62.5/125 µm	1300nm: 1 dB/km 1300nm: 1 dB/km	800 MHz*km 500 MHz*km	8 dB 11 dB	5,000 m 4,000 m
Single-Mode	9/125 µm	1300 nm: 0.4 dB/km 1550 nm: 0.25 dB/km	3.5 ps/nm*km 19 ps/nm*km	16 dB 29 dB	32,500 m 86,600 m

1) For 100 Mbit/s switch equipment. See data sheet for 1 Gbit/s equipment.
2) Theoretical max. length of cable without any splicing.
3) 50/125 µm or 62.5/125 µm Multi-Mode cable may be used, 50/125 µm is recommended.

4. Optical loss in fiber components

Each splicing, connector or patching in the fiber system introduces a certain amount of loss. The maximum allowable loss is as follows.

Loss in:	Multi-Mode	Single-Mode
Splicing	0.1 dB	0.1 dB
Connector[4)]	0.4 dB	0.4 dB

4) Loss is for each connector (a patch is 2 connectors, a switch/cable connection is also 2 connectors)

Fiber optic installations depend on the cleaning of the connectors, which means that every time a connector is taken out of its place, it has to be cleaned before being put back in place again. This operation is done with Isopropyl alcohol and special lens-cleaning tissues. It is also necessary always to mount the dust caps on adapters and connectors when not in use.

5. Connectors

The type of connectors to be mounted on fibers must be agreed upon in each specific project. Connectors of type **SC**, push-pull connectors, are recommended in EIA/TIA standards and are **preferred** by Vestas. The normal line of interface between cable contractor (if not Vestas) and Vestas is the Patch box connector adapters in the Patch box delivered from Vestas. Connectors may come with different polishing techniques, Physical Contact (PC), Ultra Physical Contact (UPC) and Angled Physical Contact (APC). The type used by Vestas shall be of Physical Contact (PC) type, also sometimes referred to as SC/PC for the SC connector type.

6. Inspection and testing

When the installation and the termination of the fiber is completed, all the fibers must be measured at two wavelengths:

- Multi-Mode at 850/1300 nm,
- Single-Mode at 1310/1550 nm

These measurements are always taken point-to-point. All fibers must be tested individually with following measurement methods (normally both methods are required by Vestas):

- **Power-through test (attenuation)** - is done with an Optical Loss Test Set. This is an end-to-end test with an optical source at one end and a power meter at other end. This test method is used to measure every single stretch of fiber cable. Measurements must be taken in both directions and measurements must be taken at two wavelengths.
- **OTDR bi-directional verify** - measured with an OTDR measurement instrument. This test method is used for measurement on cables with one or more splicings to verify the quality of the splicing. It is also useful to verify that cable bends are not to tight etc. Measurements must be taken in both directions and measurements must be taken at two wavelengths.

NOTE:
All cable connection descriptions, attenuation measurements and OTDR reports have to be delivered to Vestas and the customer as documentation on the fiber installation. As minimum this report includes for each fiber: end-to-end distance, total loss and measurement report. The OTDR report must contain an attenuation curve (OTDR trace) and must include additionally information on attenuations in each peak point (splicing, patch-connection, bend, etc.). Reports may be delivered in printed form or electronically (MS Word, MS Excel or PDF format preferred).

7. Calculating budget and fiber distances

The ideal method for determining the optical loss is to actually measure the loss once the fiber has been laid. However, for the initial fiber design, the loss must be calculated. You should always test and validate the loss once the fiber is laid. Note that all calculations assume the Full Duplex (FDX) mode of operation, which is used in Vestas' communication systems.

Two calculations can be made: *signal loss* through a known length of fiber and with a known number of splicings and connections, or *maximum fiber distance* given a known power budget and assumed maximum loss in splicings and connections.

Calculating maximum signal loss is simply the sum of all worst-case variables within each fiber segment. The numbers shown in the tables in section 2 and 3 above are the maximum allowable loss, used in the following calculations.

Signal Loss [dB] = (Fiber Attenuation × km)
+ (Splice Attenuation × # of splices)
+ (Connector Attenuation × # of connectors)
+ (Safety Margin, normally 3 dB)

The Signal Loss may not exceed the Power Budget of the switch equipment used (see values in section 3. Optical fiber cable types).

For a given power budget - and making some assumptions about the number of splices and connections - you can also estimate the distance you can run a fiber of particular specifications. Calculation of *Net Power Budget* may be done as follows, and afterwards the *maximum cable distance* can be calculated:

Net Power Budget [dB] = (Power budget from switch)
- (Losses from splices × # of splices)
- (Losses from connectors × # of connectors)
- (Safety margin, normally 3 dB)

Max. cable distance$_{PB}$ [km] = Net Power Budget / Fiber Attenuation

Multi-Mode cable tends to disperse a light wave unevenly and can create a form of timing jitter as the data traverses the cable. This modal dispersion tends to create data errors as the data rate increases.

In addition to calculating budget across Multi-Mode fiber, you also need to calculate the losses resulting from modal dispersion. The maximum link distance due to data rate restrictions for Multi-Mode fibers is as follows:

Max. cable distance$_{MD}$ [km]=Bandwidth of fiber / Signal Rate

where signal rate for different data rates is as follows:

Standard	Actual Signal Rate	Data Rate (Mbps)
10BaseFL	20 MHz	10
100BaseFX, 100BaseSX	125 MHz	100

For example, assuming you are using 100 Mbps Fast Ethernet with an actual bit rate of 125 MHz across a 62.5/125 μm Multi-Mode fiber at 1300 nm. The modal dispersion of 1300 nm Multi-Mode cable is 500 MHz*km minimum and will result in the maximum distance due to modal dispersion:

Max. Distance$_{MD}$ [km]=500 [MHz*km] / 125 [MHz]= 4 [km]

The **maximum acceptable length of your fiber** will be the **least** of the max. cable distances calculated above.

8. Definitions

ITU G 652
Defines the specification for standard Single-Mode optical fiber.

ITU G 653
Defines the specifications for dispersion shifted Single-Mode optical fiber.

ITU G 655
Defines the specifications for non-zero dispersion shifted fiber.
See: http://www.itu.int/home/index.html

EIA/TIA
The Electronic Industries Alliance (EIA) is a national trade organization that includes the full spectrum of U.S. manufacturers, representing more than 80% of the $430 billion electronics industry. The Telecommunications Industry Association (TIA), formed in 1984, as a non-profit making organisation owned by its members, is the prime national trade association for the telecommunications industry in Great Britain. TIA's role is to improve the competitiveness, global business development, technical and quality standards and staff competence of its members.
See: http://www.eia.org and http://www.tiaonline.org/standards/overview.cfm

Dispersion
Multi-Mode dispersion (Modal dispersion) and spectral dispersion cause Dispersion. Modal dispersion occurs in Multi-Mode cables where there are higher order and lower order modes so the same signal will be delayed by different amounts resulting in the spreading of the pulse. This effect does not occur in Single-Mode fibers. Spectral dispersion occurs in MM and SM cables because different wavelengths are travelling at different velocities through a medium. The factors affecting dispersion are fiber cable length, fiber specifications, data rate and wavelength. Other dispersions may occur are Chromatic Dispersion, Polarisation Mode Dispersion, etc.
Dispersion is measured in *ps/km*nm* which represents the amount of pulse spread from an ideal pulse for every km of fiber and every nm of wavelength change.

LSZH (Low Smoke Zero Halogen), FRNC (Flame Retardant Non Corrosive), LSHN (Low Smoke Non Halogen)
Cable materials for both indoor and outdoor use that do not emit toxic smoke if burning.

OTDR
Optical Time Domain Reflectometer, used to measure the length of a cable, and detect any flaws in it. Can also be used to measure end-to-end loss, although less accurately than a power meter.

OLTS
Optical Loss Test Sets: Optical Source and Power Meter used to measure the end-to-end loss through a fiber optic strand, or system of cable, connectors and patch cables. Measurements are more accurate than an OTDR.

Bandwidth
Fiber bandwidth is given in MHz*km. A product of frequency and distance, bandwidth scales with distance: if you halve the distance, you double the frequency. If you double the distance, you halve the frequency.

Attenuation
Attenuation is loss of power. During transit, light pulses lose some of their energy. Attenuation for a fiber is specified in decibels per kilometre (dB/km). Attenuation varies with the wavelength of light. There are three low-loss "windows" of interest: 850 nm, 1300 nm, and 1550 nm. The 850-nm window is perhaps the most widely used because 850-nm devices are inexpensive. The 1300nm window offers lower loss, but at a modest increase in the cost of LEDs. The 1550nm window today is mainly of interest for long-distance telecommunications applications.

Loose Buffer
The fiber is contained in a plastic tube for protection. To secure better waterproofing protection to the fiber, the space between the tubes is sometimes gel-filled. Typical application is outdoor installations. One drawback of the loose buffer construction is a larger bending radius.

Tight Buffer
Buffer layers of plastic and yarn material are applied over the fiber. Results in a smaller cable diameter with a smaller bending radius.