Network General Specification

VestasOnline™

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1. Definitions

VestasOnline™ Standard	The entry-level Web-based version of Vestas' Remote Control & Monitoring system (see VestasOnline™ Standard - General Specification, item no. 951440)
VestasOnline™ Professional	The PC based version of VestasOnline™, where a server is located in the wind power plant (see VestasOnline™ Professional - General Specification, item no. 951435).
Ethernet	Ethernet is a standard network for Local Area Networks, and is the type of network normally used for connecting PCs in office or home environments, also referred to by the IEEE 802.3 standard.
Switched Ethernet	Ethernet segmented by use of switches. On normal Ethernet all nodes are connected to a common bus, where all nodes can see/hear each other. Switched Ethernet is segmented by switches, where only nodes communicating with each other can see/hear each other.
Internet	The Internet is the international network, used worldwide for browsing home pages, e-mail transfer, etc.
LAN	Local Area Network. Network in a local area - typically an office or in this case a wind power plant. Also referred to as an Intranet.
PSTN	Public Switched Telephone Network. This is the network used for all normal telephone communication.
WAN	Wide Area Network. One or more LANs connected over large distances via Internet, PSTN or other long-range connections.
Protocol	In networking, the term protocol refers to a set of rules that governs communications. Protocols are to computers what language is to humans.
SNMP	Simple Network Management Protocol. A communication protocol used for monitoring and managing intelligent switches, PC-servers and other systems supporting the protocol.
STP	Spanning-Tree Protocol prevents loops from being formed when switches are interconnected via multiple paths. An IEEE 802.1D standardised algorithm.
VPN	Virtual Private Network. A tunnelling protocol used to make a private and encrypted connection between two parties across the Internet. See references for links to informal home pages regarding VPN.
PPP	Point-to-Point Protocol; an Internet Standard for transmission of IP packets over serial lines.

2. Introduction

The VestasOnline™ network is used for the communication with Vestas wind turbines and other equipment in wind power plants – large and small. It is the communication infrastructure in wind power plants where the VestasOnline™ system is installed. The main focus when designing the VestasOnline™ network has been to base it on widely accepted industry standards for easy setup and integration with external systems, which also ensures easy maintainability.

The VestasOnline™ network is an optical fiber based network, built on the Ethernet standard. It is configured as an intranet between the turbines and one or more main switches located at a central PC Server system, or at a Router connected to the PSTN/ISDN (Public Switched Telephone Network/Integrated Services Digital Network) or to the Internet (xDSL). Optionally a wind power plant may include radio links or wireless networks in parts of the wind power plant.
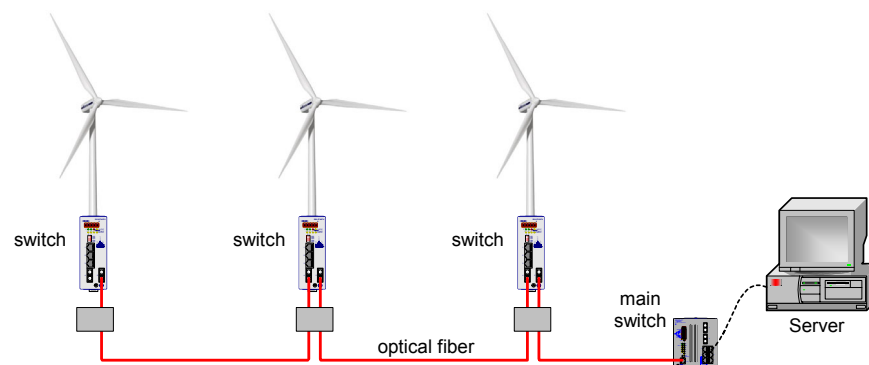

Figure 1: Example of a small simple network

Network components used in the VestasOnline™ Network are of industrial types with focus on high temperature range, EMI Immunity, surges, transients, durability (vibration), ease of service etc.

3. Basic principles in turbine

The turbine controller is equipped with a 10 Mbps (10 Base-T) Ethernet connection, which is connected to a communication switch by an UTP (Unshielded Twisted Pair) copper cable. The switch is connected to the wind power plant communication network, where fiber cables are connected between the individual turbines and to a central point. From the central point the wind power plant can be connected to a VestasOnline™ Server system or to the surrounding world via a Router. The network running between the switches is a 100 Mbps Ethernet network (Fast Ethernet).
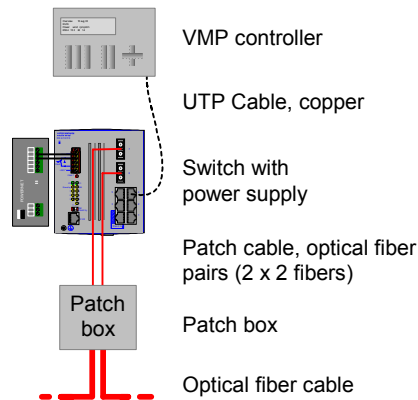
Figure 2: Network components in turbine

VMP controller

UTP Cable, copper

Switch with power supply

Patch cable, optical fiber pairs (2 x 2 fibers)

Patch box

Optical fiber cable

The optical fiber cable in the wind power plant network is led into a *patch box*, where the optical fiber cable is terminated and connectors are mounted. A fiber patch cable is then led from the patch box to the communication switch, where the optical signal is converted to electrical signals for connection to the turbine controller. One pair of fibers is used for Receiving connection (Rx) and one pair of fibers is used for Transmit connection (Tx), resulting in the use of 4 single fibers total.

4. Components

This section lists and explains the components included in the network for a wind power plant with Vestas wind turbines and any optional units.

4.1 Optical Fiber

The standard communication connection between units in a wind power plant with VestasOnline™ network is optical fibers. Two different types of fibers are used:

Multi-Mode (MM):
The Multi-Mode fiber is used typically in on-shore installations, where distances between units are below 4,000 m – 5,000 m. Cable of type 62.5/125 μm or 50/125 μm is used for Multi-Mode connections, where the 62.5/125 μm fiber will allow up to 4,000 m of distance and the 50/125 μm fiber will allow up to 5,000 m of distance. The choice of Multi-Mode fiber depends on the distance as just mentioned, but otherwise 50/125 μm fiber is the recommended type, if available.

Single-Mode (SM):

Single-Mode fibers are used where distances are between 4,000 m – 32,000 m, but also very often in off-shore installations, where the fiber optical cable is embedded in the Medium Voltage cables as this is the most cost-effective solution, when cost of MV-cabling with embedded fiber optics is taken into account. Cable of type 9/125 μm is used.

Please see Vestas document "Fiber cable handling and installation", item no. 951471 for further information on fiber cables and for information on calculating maximum allowable distances.

4.2 Optical connectors

The network fiber cable must be terminated with connectors for connections in the patch box, and the patch cables must be terminated with connectors for plugging into the patch adapters in one end and into the switches in the other end.
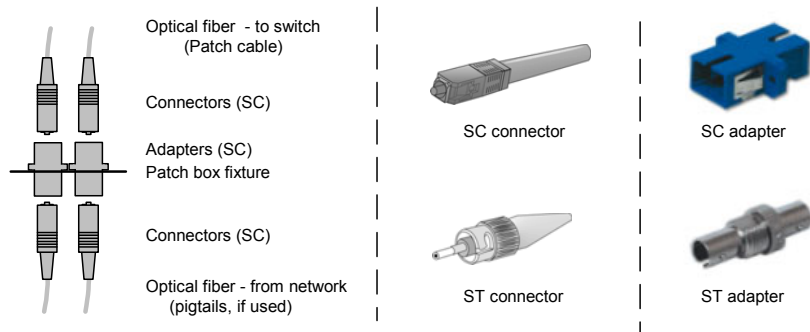

Figure 3: The internals of a patch box (one pair of fibers shown) and SC, ST connectors

The network cable – the cable laid out between the turbines – must be terminated with connectors that fit into the adapters in the patch box. **The connector type preferred by Vestas is the SC connector**, as this type is easy to plug-in, has small attenuation, and is recommended by IEC/EIA/TIA. If other connector types, e. g. ST connectors, are requested by customers, this is taken care of by using ST-type adapters in the patch box, and then use ST-to-SC patch cables, as **the switches used by Vestas are standardised to use SC connectors**.
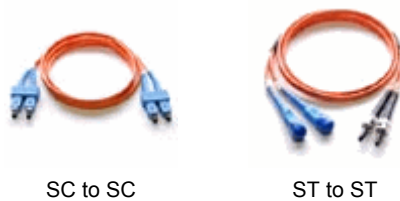

SC to SC   ST to ST

Figure 4: Patch cables (between patch box and switch)

The cable between the turbines has to be terminated with connectors in the patch boxes. There are two ways to accomplish this.

The first solution is to mount the connectors in the field, terminating connectors directly on the fiber cable coming from the ground. **This solution is not recommended by Vestas,** as this method involves handling small parts in the field and the work demands an environment with controlled temperature and cleanliness – *see Figure 5: SC and ST connector parts.* In addition to the handling difficulties, the terminated connectors have to be polished afterwards; a time consuming task, which also has to be done in the turbine – resulting in a time demanding and costly process per turbine.
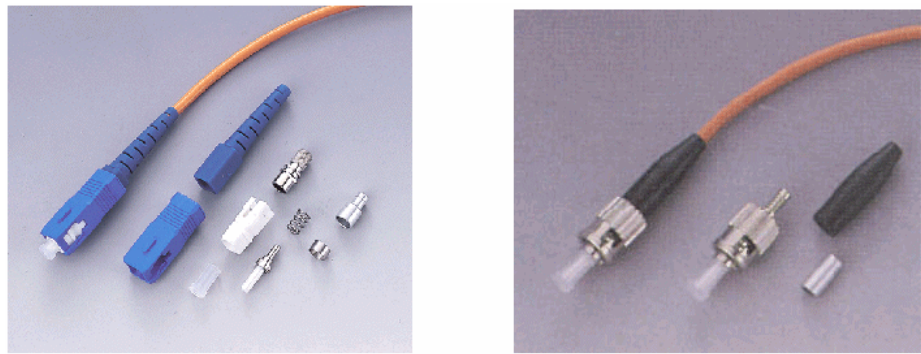

Figure 5: SC and ST connector parts

The second alternative is to use *Fiber Pigtails*, which is a short length of cable, usually tight-buffered, that has an optical connector on one end and a length of exposed fiber at the other end. The exposed fiber of the pigtail is then fusion spliced to the off-ground fiber cable. This involves only splicing fiber cables in the patch box within the turbine, which is done with advanced automatic equipment in a simple working process. The pigtails with pre-mounted connectors are assembled in a controlled environment at the manufacturer and no polishing or other work on the connectors is demanded in the field. **The use of pigtails is the method recommended by Vestas**.

The face/end of the connectors can be polished in different ways to enhance performance and minimise reflectance/optical return loss. This is a measure of the light reflected from the polished fiber end at the glass/air interface, when two connectors are put together. The standard type of connector finish is the Physical Contact (PC) polishing, which is a 90-degree polishing. The polishing may be rounded slightly to ensure that the core of the fibers connect, which is the Ultra Physical Contact (UPC) polishing. Finally the Angled Physical Contact (APC) connectors are made by introducing a slight 8-degree angle on the end face of the fiber – this demands connectors to be accurately aligned against each other. **The connector type used by the switches in a VestasOnline™ network is the standard 90-degree PC connector**.

*Figure 6: PC – UPC – APC polishing alternatives
(massive = core fiber, surrounded by cladding)*

4.3 Patch box

The patch box is a small fiber termination box offering facilities for splicing fiber-to-fiber and fiber-to-pigtail, and for handling the connector patching. A typical installation of a patch box is shown in *Figure 7: Patch box - onshore version* where one inbound fiber cable enters the patch box at the lower left, and one outbound fiber cable exits the patch box at the upper left (both black cables). The patch cables leading to the switch are the thinner, grey cables going around the left end of the box.

The inner loose-buffered fiber tubes are curled within the box to leave some extra length of fiber cable as this makes it easier to work with. Also, this leaves some extra length in case of a failure on the fiber. The box offers strain relief for the cable jacket with a tie-wrap and for the strength member in the cable (a special, normally Kevlar, strand for strain relief in the fiber cable). The inner strands of fibers (typically 4 – 8) in a tube may be curled up in routing trays to ensure the cable bending is within acceptable limits. Vestas recommends the use of 8 strands of fibers.

The trays has splice holders for safeguarding the splice protectors, which are small thin plastic tubes used for protecting the fibers against bending where the fusion splice was made.

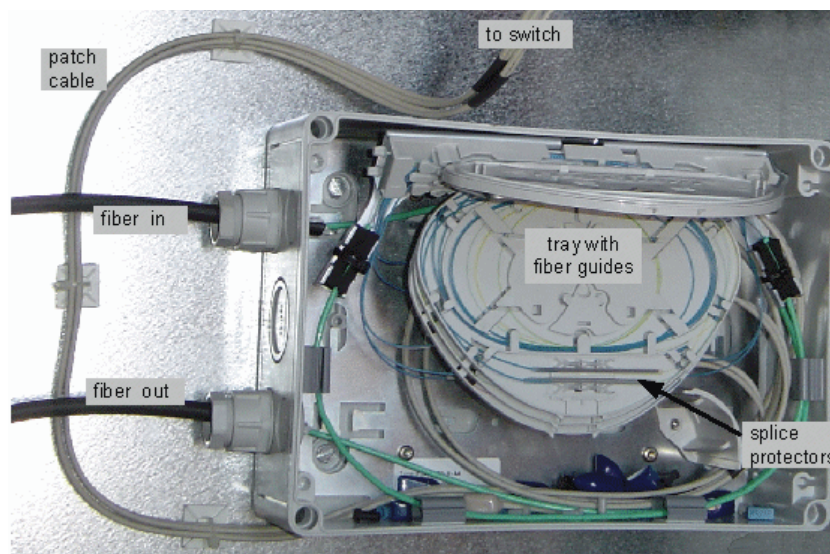*Figure 7: Patch box - onshore version*

The actual connections in the patch boxes will depend on the network topology and will be different if the turbine is used for hosting a pass-by fiber splicing or not.

The patch adapters are held in a metal frame below the splicing cassettes as shown in *Figure 8: Patch adapters and cables* with patch cables on the left side and the pigtails on the right side.
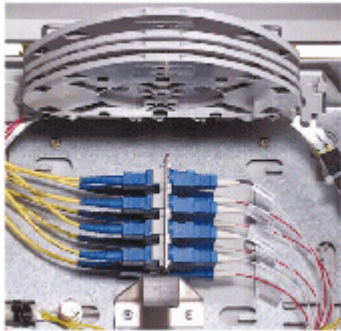
Figure 8: Patch adapters and cables

In a linear topology where all turbines are connected on one line (please see s*ection 5.1 Linear topology*), the connections are as shown to the left in *Figure 9: Connections in patch boxes - with or without extra splicing of extra pair of fibers.* The incoming fiber pair is led through the patch adapters, via the patch cable to the receiving port on the switch. A patch cable is led back through the patch adapters from the transmit port on the switch, and out through the outgoing fiber pair.
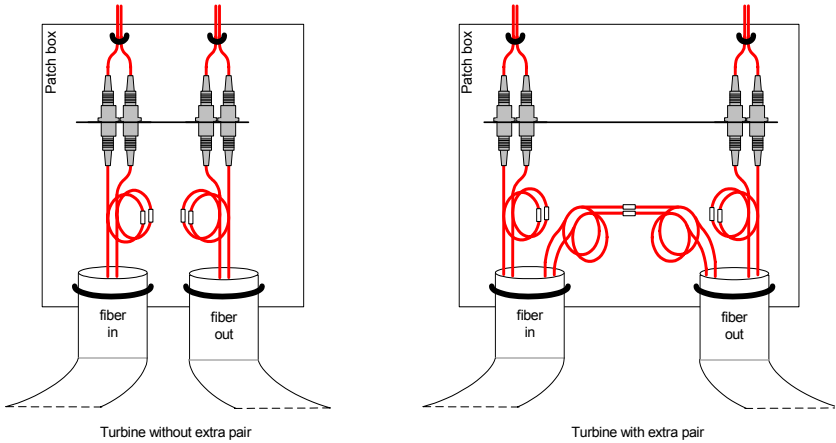

Figure 9: Connections in Patch boxes - with or without splicing of extra pair of fibers

The figure also indicates that the part of the fiber cable pairs from off-ground to the patch adapters is pigtails spliced onto the off-ground fiber cable (every line represents one fiber strand).

In a ring topology where every second turbine is bypassed in one direction (please see *section 5.2 5.2 Ring topology, type 2*), the connections are as shown to the right in *Figure 9: Connections in Patch boxes - with or without splicing of extra pair of fibers.* The fibers in and out of the turbine, where the patch panel is mounted, are led through exactly as explained above, but two extra pairs of fiber cables are also led into the patch box where they are spliced together to make a pass-by connection.

4.4 Switch types

The communication switches used in the VestasOnline™ network is industrially hardened switches, for achieving a reliable and highly stable network within wind power plants. Different switches may be used in the turbines plus other units distributed in the wind power plant and at the central point of connection to a central server or directly to the surrounding world via Routers. Selection of switches depends on the farm layout, type of VestasOnline™ system etc. – see section *8. Design rules* for selecting appropriate types of switches and network layout.

4.4.1 Turbine switches

The switches in the turbines – or any other unit – in a wind power plant may be of two principally different types, *managed* or *unmanaged* switches. Both types are fan-less switches with no moving parts and no battery or UPS that need maintenance.

<u>Managed switches</u>
Managed switches has built-in intelligence, which facilitates monitoring of the health of the switch itself and its ports plus management of the switch configuration, traps settings etc.

Figure 10: Managed switch with 2 FX ports and 5 TX ports

The managed switches enables the VestasOnline™ supervision system to show the status of the switch and its different ports on-screen, and enables monitoring of the status of these with alarms and notification in case of errors or problems.

The managed type of switch also has some advanced features for handling redundancy in ring-structured networks with very low switch-over times (see sections on Network Topology later in this document).

This type of switch is recommended particularly for use in off-shore wind power plants, but is also the choice if specific requirements demand fast switch-over times (< 500 ms) in redundant network layouts.

Typical characteristics for managed switches:

Switch-over time
Less than 500 ms

Monitoring of switch status
Possible via SNMP (optionally included in VestasOnline™ Professional / Enterprise)

Configuration of switch IP-address
Possible via Telnet or Web-interface (Browser). Requires an IP-address in the
network address space to be addressed for monitoring and management (must be
set-up initially).

Port configuration
2 optical fiber ports (2 FX, 100 Mbps, SC connector) and 5 copper ports (5 TX,
10/100 Mbps, RJ45 sockets)

Supported media
Multi-Mode (MM) or Single-Mode (SM)

The managed switch is also available in a Long Haul (LH) type, supporting
distances between 32 km and 86 km on Single-Mode fiber. Please notice that
Long Haul switches are very expensive, costing 2 to 3 times as much as a
standard managed switch!

Unmanaged switches
Unmanaged switches have the same basic switching functionality as the
managed switches, except there are no monitoring or management facilities.

Figure 11: Unmanaged switch with 2 FX ports and 3 TX ports

Furthermore there are no facilities supporting redundant network layouts with
fast switch-over times – redundant network layouts may still be built with the
unmanaged type of switches, but the switch-over times may be as large as 300
seconds in case of an error in the network. Linear-topology networks may also
be built with unmanaged switches, where no switching-over is required.

**The unmanaged type of switches are recommended for small simple
networks where fast switch-over times are not demanded, and where focus
is on cost-effective systems.**

Typical characteristics for unmanaged switches:

Switch-over time
Less than 300 seconds (5 minutes)

Monitoring of switch status
Not possible

Configuration of switch IP-address

Not possible (but also not required). Does not take up an IP-address in the network address space.

Port configuration

2 optical fiber ports (2 FX, 100 Mbps, SC connector) and 3 copper ports (3 TX, 10/100 Mbps, RJ45 sockets)

Supported media

Multi-Mode (MM) or Single-Mode (SM)

4.4.2 Central switches

The central or main switch in a typical wind power plant is the switch at a central point of the wind power plant, where the network between the turbines and other units are connected to a central VestasOnline™ Professional / Enterprise server system, or to a router access point for smaller VestasOnline™ Standard systems. If redundancy is required, the central switch may actually consist of two interconnected switches to ensure that one switch is always online.

Small and simple networks

In small and simple network layouts, the central switch is of the same type as the turbine switches. Managed or unmanaged type may be selected depending on whether a redundant layout is demanded, or whether a very simple linear-topology layout is sufficient (no redundancy). See *Section 5*. *Network topology* for more information on different topologies and redundant versus non-redundant layouts.

If ring topology with redundancy is required, the central switch **must be managed** in order to act as a master switch in the network. For fast switch-over times, managed switches must be used throughout the whole network and at the central point, but if fast switch-over time is not required, only the central switch needs to be of the managed type. The choice will be a compromise between speed and cost. A managed switch costs approximately twice as much as an unmanaged switch.

Large and advanced networks

For larger networks, or for wind power plants where requirements are higher, the central switch consists of a modular Gigabit Ethernet backbone switch. The modular switch is available in 3 different sizes, Model 1, Model 2 and Model 5 – the number reflects the amount of basic boards in each (see table and figure 14 later).

All models consist of a chassis with a passive backplane (low risk of failure), cooling fan, power supply unit and a basic board. LED indicators on the front show status of board and modules for quick visualisation of status additionally to what can be monitored via SNMP. Power supplies may be redundant or even tripled in the bigger models for added reliability.

Figure 12: Gigabit Ethernet switches, Model 1, Model 2 and Model 5

The basic board is the interface card for connecting different network media modules. Each board is completely independent to ensure high reliability. It has the complete logic for controlling the data traffic and access to the system bus for data exchange with other basic boards, if fitted. It has its own management agent with IP address and MAC address (the address on the Ethernet level) and has 4 sockets for connecting media or Router modules. Media modules form the direct interface for connecting to network segments. One basic board may be replaced while the network is running on another board (if 2 or more basic boards are installed).
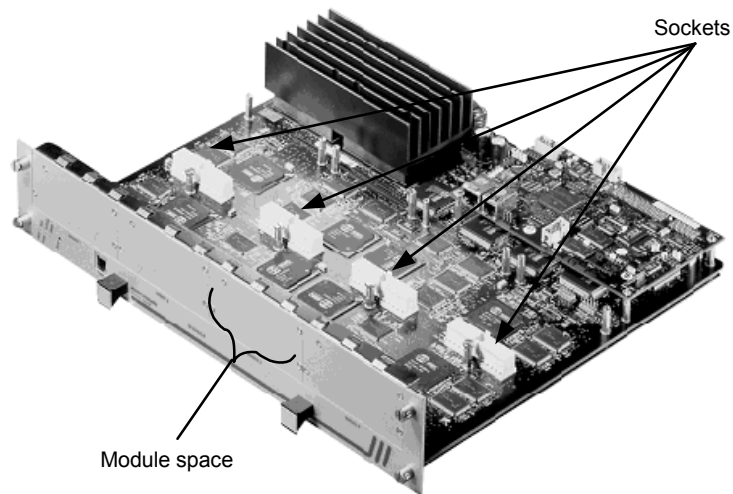

Figure 13: Basic board with no modules mounted

The basic board may hold 1 – 4 media modules, which can be any of the following types:

| Module type	Media	Sockets	Configuration
8-port fast ETHERNET	twisted pair	8 x RJ45 sockets	10BASE-T/100BASE-TX
8-port fast ETHERNET	optical fiber (MM only)	8 x MT__sockets	100BASE-FX
2-port gigabit ETHERNET	twisted pair	2 x RJ-45 sockets	1000BASE-TX
2-port fast ETHERNET	optical fiber (SM/MM)	2 x SC sockets	100BASE-FX
2-port fast ETHERNET	optical fiber (SM/MM)	2 x SC sockets	100BASE-FX
1-port Gigabit ETHERNET	optical fiber (SM/MM)	1 x SC socket	1000BASE-FX
2-port Gigabit ETHERNET	optical fiber (SM/MM)	2 x SC socket	1000BASE-FX
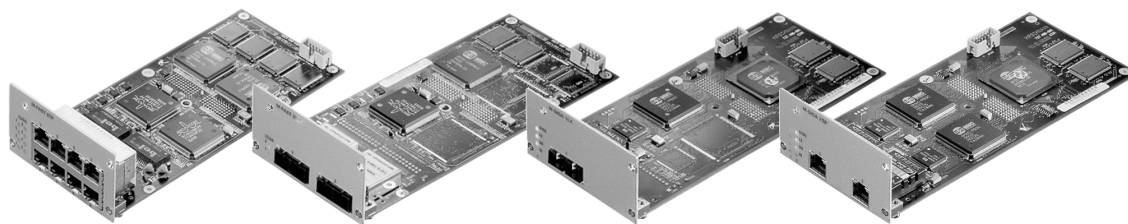
Figure 14: Media modules (8 x TX, 2 x SC, 1 x SC, 2 x TX)

The modular Gigabit Ethernet switches provide space for a different number of basic boards and thus a different number of media modules.

Gigabit Ethernet switch	Model 1	Model 2	Model 5
No. of power supplies	230 VAC, 24 VDC, 24 VDC	230 VAC, 230 VAC	230 VAC, 230 VAC, 230 VAC
No. of basic boards	1	2	5
No. of media modules	4	8	20

The number of power supplies indicates the maximum configuration. All switch models are always delivered with minimum one 230 VAC supply, but additional supplies are possible if redundancy is required.

The required number of ports for a given wind power plant will decide which type of Gigabit Ethernet switch to select, and how many basic boards and media modules to install in it. **There must always be at least one 8 x TX module** mounted for connection to the PC server system – two 8 x TX modules are needed with large PC server systems.

The Gigabit Ethernet switches can handle redundant ring structures via a fast recovery technology (switch-over time > 500 ms) if a single central switch is used. Ring structures for dual central switches are supported by configuring the central switches to use the Spanning-Tree Protocol (switch-over times 30 – 90 seconds).

The central Gigabit Ethernet switches are mounted in a 19" rack – in the same rack as the PC Server system in small installations, or in a separate rack in large installations.

5. Network topology

The network layout may follow different topologies, depending on the actual wind power plant Medium Voltage cable layout – as the communication cables almost always follow these. But even within a certain MV cable layout, the fiber cable layout may be designed in different ways depending on requirements to redundancy, safety, stability, switch-over time and others.

Different possibilities may apply for on-shore wind power plants or off-shore wind power plants. As off-shore wind power plants are less accessible the requirements to the reliability, fail-over safety and up-time on the network are normally much higher than for on-shore networks.

Patch boxes are used in real life installations, but not shown on the sketches in this section, as the figures are meant to give a clear overview of different topologies.

5.1 Linear topology

Linear topology is only recommended in small and simple installations with few wind turbines. In linear topology wind power plants, the units are connected in a daisy chain as shown in *Figure 15: Linear topology.* The blocks 1 - 5 represents the turbine switches, the 'CS' block represents the Central Switch, and the line represents a pair of fibers (transmit and receive path). The PC represents a PC Server system in VestasOnline™ Professional and VestasOnline™ Enterprise, but will only be a Router in VestasOnline™ Standard systems.
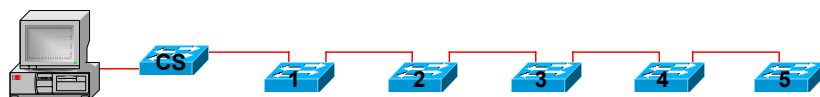

Figure 15: Linear topology

The linear topology is easy to install and understand, but has the disadvantage that if one switch breaks down, or is without power, the rest of the line is disconnected (e. g. if switch 2 is down, communication to 3, 4 and 5 is lost).

Pros:

- easy installation (only mounting of connectors on optical fiber needed)

- easy to understand and plan

- uses minimum amount of fiber pairs

Cons:

- very poor reliability/safety (failure at one point disconnects rest of line)

5.2 Ring topology

Ring topology is the preferred network topology as it is an excellent compromise between reliability and safety versus cost and complexity of installation. Ring topology connects the turbine switches in a ring structure with a redundant communication return path (dotted line) as indicated in *Figure 16: Ring topology - type 1.*
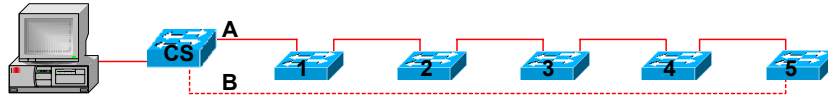

Figure 16: Ring topology - type 1

This shows the functional layout with the turbines connected in daisy chain as in linear topology, but a return path has been added to secure an alternative path to sections of the network in case of a disconnection in a switch or in the fiber cable. The normal path of communication is from A to $1 - 2 - 3 - 4 - 5$, and the return path from 5 to B is not normally active. This is handled by the intelligent (managed) central switch CS, controlling the ring structure. If switch 4 breaks down, the central switch will detect this and open port B and the path of communication will be from A to $1 - 2 - 3$ and from B to 5. This straightforward layout can be used if the fiber cable distance in the return path does not exceed the maximum distance for the given fiber. The return path may be a separate one, which ensures maximum redundancy/security, or it may be within the same fiber cable on another pair of fiber strands (will require splicing of this pair in every turbine on the return path). Please see Vestas document *"Fiber cable handling and installation", item no. 951471* for information on calculating maximum fiber distances.

Pros:

- separate return path will ensure higher reliability

- simple to design and install

- easy to understand and diagnose

- one failure/breakdown on switch or fiber cable possible without loss of
  communication to other switches

Cons:

- maximum distances for return path is limited for Multi-Mode fiber

- very often an alternative return path is not a possibility

In many cases there is no alternative return path, as the MV cables are laid out with no alternative return path. This is overcome by making a ring structure in the fiber cable layout: the switches are only connected in every second turbine on the out-going path, and from the end turbine in a row, the switches by-passed before are connected as shown in *Figure 17: Ring topology - type 2*. The small dots in the figure represents splicings on the fiber pairs, as a pair of fibers bypasses the switch in every second turbine.
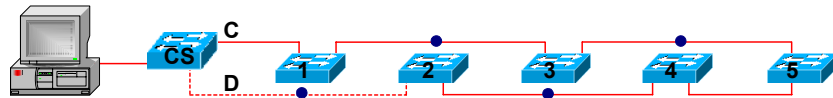
Figure 17: Ring topology – type 2

This layout allows for almost unlimited amount of turbines in a ring structure, but limitations in address tables in the switches only **allow a maximum of 50 turbines on one ring**. In general, the maximum number of switches in one ring should be kept lower, as a segmented network layout minimises the impact of a failure on a switch. It is advisable to limit the number of turbines on a ring though, as the number of inaccessible switches will increase on large rings, if more than one switch is down at one time.

The normal path of communication is from C to 1 – 3 – 5 – 4 – 2, and the redundant return path at D is not normally active, which is controlled by the central switch connected to both C and D. If a breakdown appears in the fiber cable between switch no. 1 and 3, the path of communication will be from C to 1, and from D to 2 – 4 – 5 – 3. An other way of presenting this type of ring topology is shown in *Figure 18: Alternative drawing of ring topology - type 2*, where the order of the turbines is just alternating on the ring to clarify the logical communication path.
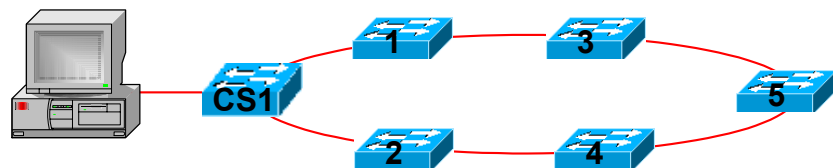

Figure 18: Alternative drawing of ring topology - type 2

The ring topology (both layouts) can accept the breakdown of one fiber or switch without affecting other connections. There will be a switch-over delay of less than 500 ms (fast recovery – all switches managed), 30 – 90 seconds (Spanning Tree Algorithm) or up to 300 seconds (unmanaged turbine switches with small managed central switch). If more than one breakdown occurs, the switches/ turbines between the two outmost switches will be inaccessible.

Pros:

- high reliability (redundant path to central switch)

- cost-effective (no extra digging of trenches in 'virtual ring' layout)

- relatively simple to design and install

- relatively easy to understand and diagnose

- one failure/breakdown on switch or fiber cable possible without loss of
  communication to other switches

- no real limitation on distances, as signal is refreshed in every second turbine

Cons:

- extra splicings in turbines

A drawing of how fibers are wired through the system is given as an example in *Figure 19: Details of ring topology - type 2 network.* A large scale copy of this drawing is also available as *Figure 29* in Appendix A.
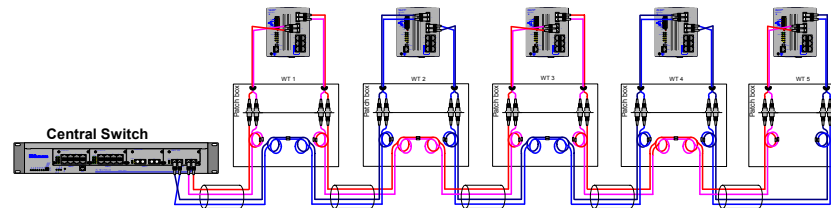

Figure 19: Details of ring topology - type 2 network

5.3 Star topology

The central switch (CS) is placed at a central point and all network connections are connected in a star formation as lined out in.
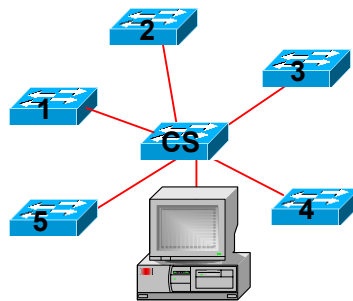

Figure 20: Star topology

The star topology connects all turbine switches directly to the central switch, via separate fiber cables – each turbine has its own connection. This is a very fail-safe layout, but it demands as many ports in the central switch as there are turbines in the wind power plant, which will be very costly in large wind power plants. Also, the fiber cabling normally follows the MV-cabling, and in most cases the MV-cabling will not be in a star formation. All distances must be less than the limitation of the selected fiber cable type (MM/SM).

Pros:

- independent fiber cable connections (breakdown in one connection does not affect others)

- easy to diagnose

- easy to install

Cons:

- very costly in terms of used ports on central switch

- costly due to length of cable required

- not many MV cable layouts follow a star structure

5.4 Variations on topology

In some cases, the layout of the wind power plant network may have additional switches and fiber cable stretches. Examples of this is for off-shore wind power plants where a platform is placed near the turbines, to have one common point of connection for mainly MV-cabling, but also for communication cabling.
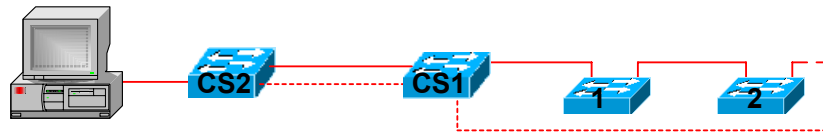

Figure 21: Dual Central Switch example

The connection between CS1 and CS2 is often a long distance (10 – 20 km) Single-Mode fiber cable. To have redundancy in case of failure on a connector or on a switch port, an extra fiber cable pair should be used on this connection. Optionally a radio link may be used as a redundant connection, but the use of radio link is possible over limited distances, especially when crossing water. Inclusion of radio link option is always to be investigated further – many local limitations may apply (licenses, no line of sight, distances etc.).

6. Network management

Switches with management may be diagnosed and configured by using built-in tools (into the switches) via Web browser interface, via specialised Network Management Software or via special SNMP based software tools (optional).
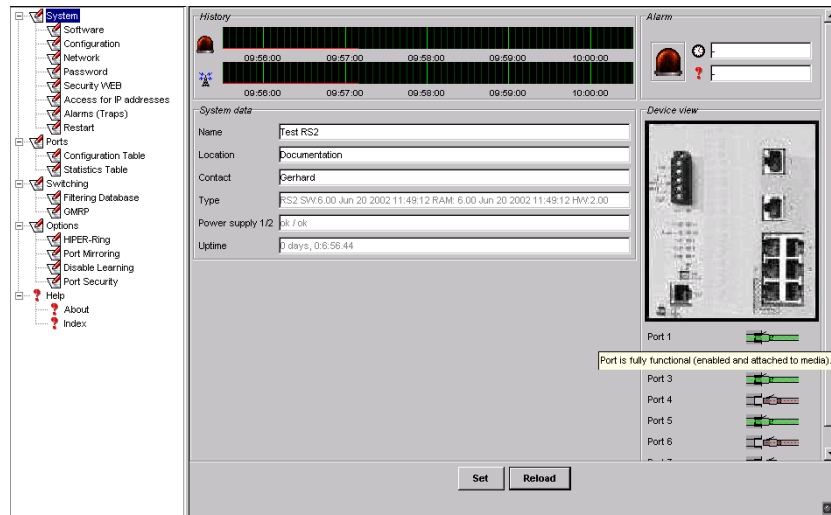

Figure 22: Management of turbine switch - Web browser interface

Status monitoring of managed switches is included in VestasOnline™ Professional and VestasOnline™ Enterprise. This will enable operators to view status of network segments and port status of the switches in the whole wind power plant. This will be very helpful if network problems are to be tracked down.

7. Solutions

7.1 Fiber cable networks

Optical fiber cable network is the preferred and by far most used solution. The solution is technically simple, it is a cost-effective solution in most cases and most importantly it ensures the fastest communication speed. This is the basic type of network used in all VestasOnline™ systems.

The topology depends on the physical layout of the wind power plant, but also on the importance of redundancy and safety required by the customer. In small simple wind power plant layouts, the linear topology may be sufficient, but the ring topology is recommended by Vestas, as it guarantees a far more reliable network. For larger wind power plants the ring topology is highly recommended and for off-shore wind power plants it is the required solution.

7.2 Wireless networks (short distances) – OPTIONAL

Wireless networks following IEEE 802.11b standard can be used within wind power plants (option). The wireless network equipment operates at air interface speeds of 11 Mbps and uses the unlicensed 2.4 GHz band. There will be a lower effective data rate 5.5 – 1 Mbps running half duplex. Maximum distances are 10

– 25 km, depending on type of antenna. The longer the distance, the lower the throughput. Wireless network is not usable for large distances passing water.

Advantages are independency of cable paths and relatively low prices, while the limitations are small distances only and relatively low speed.

Special analysis of sites must be performed before installing wireless networks - line of sight evaluation, local regulations has to be followed, etc. Any inclusion of wireless networks in a layout must be carefully investigated and designed for any specific location.

The equipment offered by Vestas is specialised wireless transmitters/receivers developed for outdoor use - not standard off-the shelf wireless network adapters as used in home/office environments.

7.3 Microwave Radio (long distances) - OPTIONAL

Special Microwave Radio links may be installed after careful investigation of local regulations, line of sight evaluation, request for available frequency bands (licenses must be purchased in most areas), etc.

Advantages/limitations: as for wireless networks, but longer distances are possible and higher communication rates are available (2 – 34 Mbps). Prices for radio links are quite high.

The use of Microwave Radio link systems are optional, and are in all cases subject to specific investigation of type, frequency band, antenna size required, licensing, etc. There is no such thing as an off-the-shelf radio link package!

7.4 Remote connections

All wind power plants with a VestasOnline™ system will need some kind of access point to/from the surrounding world. This access point or connection can be of different types, depending on which accessibility is wanted and which is possible. Connections can be point-to-point connections to a normal PSTN phone line (analog line) or an ISDN line (digital line) or it may be a point-to-many connection, where the wind power plant is connected to the Internet via ADSL (always-on digital line) or any other Router connection.

7.4.1 Point-to-point, dial-up connection

Point-to-point connections are used where the Client PC connects to the wind power plant via a point-to-point, dial-up connection. Routers at the Client PC and at the wind power plant end handle the dial-up connection.
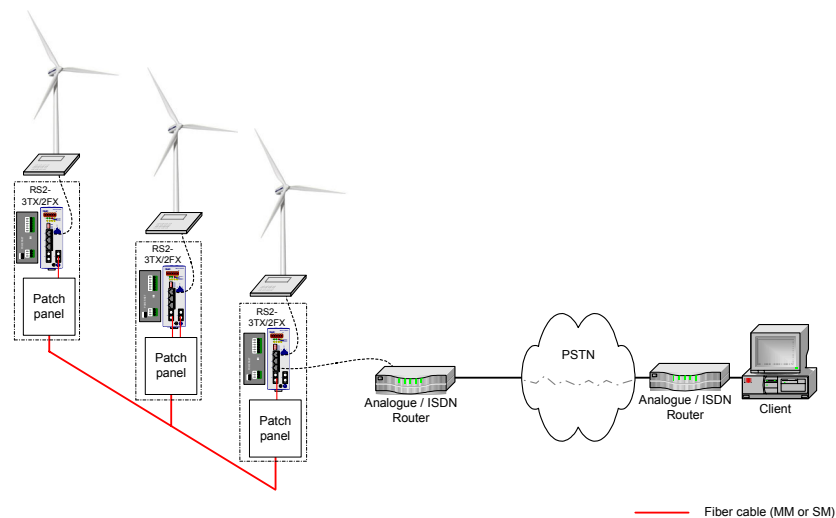

Figure 23: Analog/ISDN connection to wind power plant

Analog Router

The types of Routers available are an analog type for normal telephone line connection or ISDN type for ISDN lines. The type of Routers must be the same at both ends (analog <−> analog or ISDN <−> ISDN).

The analog Router used by Vestas is a Westermo PPP Router (<u>P</u>oint-to-<u>P</u>oint <u>P</u>rotocol - an Internet standard for transmission of IP packets over serial lines). Further technical information is found in the data sheet for the Westermo PPP Router. The Westermo Router uses a standard analog modem for the line interface as the Router handles the Router functionality only.

The Router/modem combination **demands** an analog line of appropriate quality for modems - **minimum 28.000 Baud.**

Figure 24: Westermo PPP Router, analog modem and principal setup

The analog line connection is only recommended if no ISDN or ADSL connection is available on-site, as the connection speed will be lower for the analog line, and the communication on analog lines is more sensitive to interference from noise etc.

The maximum speed for analog lines are 56 kbps and only one client can be connected to an analog Router at a time (no simultaneous connections possible).

ISDN Router

The standard ISDN Router used by Vestas is a Cisco ISDN Router. This ensures a reliable connection from Client PC to the wind power plant network, and the choice of Cisco ensures worldwide support.
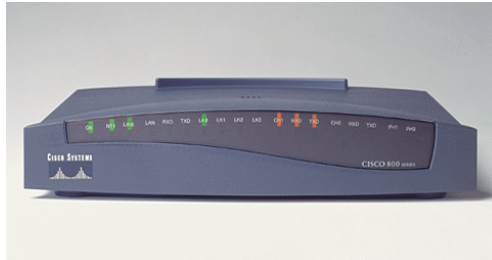

Figure 25: Cisco ISDN Router

The router has these connections:

Ethernet LAN	WAN	Analog Telephone Ports	Console Port
4-port hub 10 BASE-T (RJ-45)	1 ISDN BRI S/T (RJ-45)	2 (RJ-11)	1 RS-232 port (RJ-45)

The Cisco Router demands an ISDN2 line connection to the PSTN system, provides a four-port 10 BASE-T Ethernet hub for four direct connections to network devices such as an Ethernet switch, a turbine or a PC. It also has two RJ-11 interfaces for telephone devices such as telephones or modems, and it has a Console port for configuration. Further information is found in data sheets from Cisco.

ISDN lines guarantee a bandwidth of 64 kbps per channel and in contrast to analog phone lines; a basic-rate ISDN line provides two channels for data communication. By bundling both channels in one connection, the bandwidth can be doubled to 128 kbps. This will limit the access to maximum one client connection at a time. Two clients may be connected at a time if the channels are not bundled – each having a connection at 64 kbps.

7.4.2 Point-to-many, always-on connection

The point-to-many connections are used where the wind power plant is connected to the Internet and Client PCs are also connected to the Internet. The privacy of the connection from Client PC to the wind power plant Router is secured by use of a Firewall with VPN (Virtual Private Network) facilities built-in.
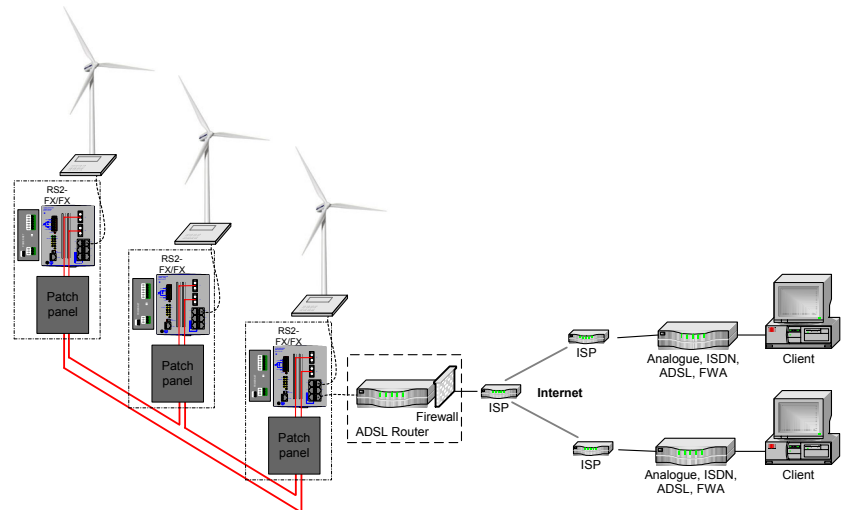

Figure 26: ADSL connection to wind power plant

ADSL Router

The Cisco PIX Router/Firewall is the standard always-on broadband connection used by Vestas. This ensures a secure and fast connection from Client PCs to the wind power plant network, and the choice of Cisco ensures worldwide support.

Figure 27: Cisco PIX Router/Firewall

The PIX Router/Firewall has these properties:

Ethernet LAN	WAN	Encryption	Console Port
4-port switch 10/100 BASE-T (RJ-45)	1 port 10/100 BASE-T (RJ-45 connector)	DES, 3DES or AES IPsec	1 RS-232 (RJ-45)

A maximum of 10 simultaneous VPN clients can be connected at a time.

The Cisco PIX Router/Firewall demands a high speed broadband connection to the Internet – in most cases an ADSL line. The interface to the broadband connection is a 10/100 BASE-T RJ-45 socket. The PIX Router/Firewall also includes an integrated 4-port Fast Ethernet (10/100 BASE-T) switch for connection to the wind power plant network. Additionally it has a console port

for configuration. Further information is found in data sheets for Cisco PIX Router/Firewall.

A broadband line may be any speed combination from 256/256 kbps and upwards. It must have a static IP-address for access to the wind power plant from the outside world. One connection into the wind power plant will enable up to 10 clients to connect at a time via their individual VPN Clients. The VPN Clients on the remote PCs are software based Cisco VPN clients that may be used to connect the remote PCs from any Internet connection.

8. Design rules

This section will define some basic design rules for planning a wind power plant network with optical fiber cables of either Multi-Mode or Single-Mode type. These rules are recommendations to follow when planning a wind power plant network layout and selecting the right components.

8.1 Single-Mode / Multi-Mode fiber cable selection

The first thing to consider is selection between Multi-Mode or Single-Mode fiber cable or selecting a mix of these. This decision is primarily based on the distances between the units (turbines, meteorology masts, etc.) but may also be based on the availability and price of the fiber cable.

The selection of fiber cable type based on distance should follow these guidelines:

Distance between units < 4,000 m
Multi-Mode may and should be used if no other requirements demand otherwise (availability, price, local demands). If 50/125 μm fiber cable is used, the distance may be maximum 5,000 m.

Distance between units > 4,000 m
Single-Mode must be used. Maximum length is 30,000 m.

Distance between units > 30,000 m
Single-Mode must be used and Long Haul switches/modules must be used. Maximum length is 86,000 m.

A mixture of fiber types (MM/SM) may be used in some wind power plant layouts where some cable stretches are very long (> 4,000 m) in some parts, but the majority of distances are shorter. This will require some 'bridging' between SM and MM fibers/switches, which is handled by installing both MM and SM switches in the same turbines at points where different fiber cables are joined. The MM and SM fiber switches are then connected with a UTP (copper) cable.
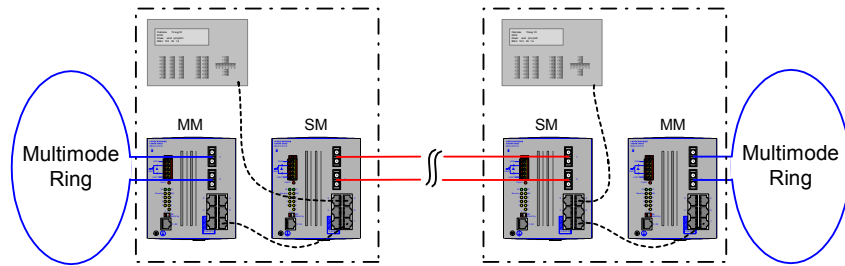
Figure 28: Single mode to Multi-Mode conversion

If fiber cables are to be embedded in the High-Voltage cables, as is the case for most off-shore wind power plants, Single-Mode fibers are commonly the most cost-effective solution. Prices for Single-Mode fiber are lower than prices for Multi-Mode fibers due to a massive use of Single-Mode fibers in the telecommunication and utility industry. Contrasting to this, the prices for Single-Mode components (switches, converters, etc.) are approximately 2-3 times higher, but savings on cable prices normally outweigh the rise in component prices.

9. Specifications

Requirements for fibers:
See Vestas document "Fiber cable handling and installation requirements"- item no. 951471 for further information of fiber cable requirements.

Turbine switches:
See data sheets for RS2-switches from Hirschman

Central switches:
See data sheets for RS2-switches and MACH 300X from Hirschman

Routers/Firewall:
See data sheets for Westermo and Cisco Routers and Firewalls.

10. Installation requirements

The Vestas wind turbine software release must be 2.06 or higher, and the wind turbine controller system must be VMP 5000.02 or VMP 6000 series with Ethernet interface (10 BASE-T).

The switches and Patch boxes are mounted within each turbine controller cabinet at the bottom of the turbine tower according to the appropriate work instructions for VestasOnline™ Network installation.

Routers and Firewalls are mounted where the connection line to the outside world is led in. This can be in a turbine or in a control building, but it has to be agreed upon in each project. The type of connection also has to be clarified.

Fiber works has to be finalised and fiber networks has to be measured and documented before installation of network components and VestasOnline™ server systems can begin. The wind power plant site has to be energised and the turbines have to be powered and operate before system tests can be made and finalised.

11. References

These references have additional information on subjects covered in this document.

11.1 Vestas documents: "Fiber cable handling and installation requirements", - item no. 951471

"VestasOnline™ Standard - General Specification", - item no. 951440

"VestasOnline™ Professional - General Specification", - item no. 951435

11.2 Internet links: Ethernet:

http://www.cisco.com/univercd/cc/td/doc/cisintwk/ito_doc/index.htm,

http://computer.howstuffworks.com/Ethernet.htm

Optical fiber cables / connectors:

http://www.fiber-optics.info

Spanning Tree Protocol (STP):

http://www.cisco.com/univercd/cc/td/doc/product/rtrmgmt/sw_ntman/cwsimain/cwsi2/cwsiug2/vlan2/stpapp.htm

Virtual Private Network (VPN):

http://computer.howstuffworks.com/vpn.htm

Routers:

ADSL:

http://www.cisco.com/go/pix

ISDN:

http://www.cisco.com/en/US/products/hw/routers/ps380/index.html

Analog:

http://www.westermo.com/Resource.phx/content/products/ethernet/
serial-ethernet-router/ed-20.htx
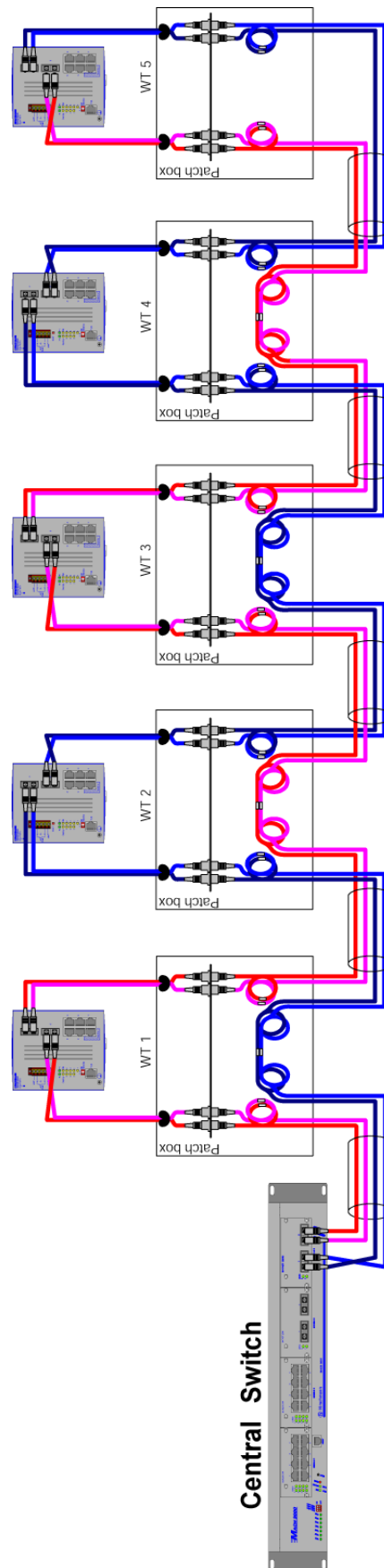
Appendix A

*Figure 29: Details of ring topology - type 2 network
(large scale drawing - identical with figure 19)*