Jomitek Lightning Down Conductor Sensor

- User manual-

- July 14, 2023 -

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1 Introduction to the Lightning Down Conductor Sensor

1.1 The Down Conductor Sensor at a glance

The primary purpose of the Jomitek Lightning Down Conductor Sensor system is to detect partially or fully disconnected sections of a lightning down conductor cable within a wind turbine blade, as it branches out to lightning receptors on the surface of the blade. This is achieved via comparative measurement of the atmospheric charge generating a voltage potential difference between each blade and the hub ground potential.

As a secondary purpose, the system is able to provide a graded and highly time accurate precipitation warning, via analysis of the distinct atmospheric charge pattern arising from precipitation (rain, hail, snow, etc.) falling onto the blades. Such warning may be used by the wind turbine control system to lower the rotational speed of the blades during active down pour, in order to reduce wear of the leading blade edges.

The Jomitek Lightning Down Conductor Sensor system consists of 3 sensor units, one for each blade of a wind turbine, as well as an interface box. Each sensor box must be located at the root of a blade, where the lightning down conductor cable enter the rotor hub, inserted in series with the lightning down conductor. The Down Conductor Sensor acts as a spark gap during lightning events, to ensure sustained functionality of the lightning down conductors. It is a strict installation requirement that the down conductor is only galvanically connected to the hub via the sensor box.

The Down Conductor Sensors require no external power supply, and feature a single fiber connection going from each sensor to the interface box. The Interface box does require a power supply, and may use either a 230VAC supply, or a 12-24VDC supply. Connectivity is supported via Ethernet for full control and operational overview, as well as via relay signals for low level alarm signalling to the turbine control system.

For the latest documentation and software, please visit the Jomitek Lightning Down Conductor Sensor support web site at http://jomitek.dk/en/products/ldcs

1.2 First time quick start guide

Note that any turbine vendor specification for exact placement, installation and test procedures must be followed, and superseeds below steps. The RJ45 connector used must be a match for the IP67 receptable of the interface box (see fig. 1). Otherwise the device IP rating is degraded to IP22, which implies a tightly controlled environment must be ensured in terms of dust and moisture levels throughout the operational lifetime. If the RJ45 connector is not in use, it must be sealed with a matched blind plug.

Figure 1: Connectors at the bottom of the interface box.

Installation

1. Attach the interface box to a DIN rail inside the wind turbine rotor hub.
2. Connect an external power supply using either 230VAC via an IEC C13 connector, or a DC power supply in the range 12-24VDC using the included M12 8-pole connector. On request, power supply may also be supported using Power over Ethernet (PoE).
3. Mount 3 sensor boxes where convenient, in the area where the blade root attaches to the hub. The exact placement, and potential use of custom mounting brackets depend on the wind turbine make and model. Jomitek is available for free consultation on mounting principles and practises. It will typically be necessary to disconnect a bolted connection terminating the blade lightning down conductor from a termination point in the hub, in order to insert the Down Conductor Sensor in series with the lightning down conductor, following the pictogram on the sensor box, see fig. 2.
4. Connect each box with the respective fiber connection on the interface box. It is strongly recommended to ensure a match between the designated blade number or letter, as defined by the turbine vendor, and the numbered connections to the Jomitek interface box. I.e. blade ’A’/’1’, should use connection ’1’ on the interface box and so forth, to avoid any confusion when identifying a blade at fault.
5. Terminate the relay wires from the M12 8-pole connector at a point where the signals can be routed to the wind turbine control system, or any parallel monitoring system of relevance. NOTE that this step may be disregarded if the relay signals are routed via Ethernet connectivity, e.g. using the MODBUS or IEC-60870-5-104 communication protocols.
6. Connect an Ethernet cable to the interface box, going to a connection point with the turbine control system, or any parallel system used for monitoring purposes. By default a DHCP server should be present on the network. On request, the Down Conductor Sensor can be delivered with a statically configured IP. If only basic relay functionality is required, the RJ45 Ethernet connection can be left with a blind plug in place.
7. Secure the routing of all cables introduced, to avoid any kind of hazard, both personal and for the sustained function of the cable connections.
8. Functional verification: Verify that ’Power on’ is lit. Using the ’Test alarm’ buttons (see description below), verify that alarm signalling is received by a supervision system with the interfacing used, i.e. via Ethernet and/or relay signalling connectivity. Test that ’Charge activity’ lights up, according to the test description in the following.

Figure 2: The Down Conductor Sensor including a connected fiber.

Front panel LED indications on the interface box

- 'Charge Activity' will flash green, when light pulses are detected via at least one of the three optical inputs. A simple test to verify this functionality is by waving a light source in front of the open input terminals, or at the other end of an inserted fiber.
- 'Power on' indicates with a green light that the interface box is powered and active.
- 'Conductor alarm' will light up for the respective blade sensor, if relevant. As autonomous alarm detection require a long duration data recording (often lasting days), they will not light up during installation, even if one or more fibers are disconnected.
- 'Test alarm' will manually force alarm indication for all inputs, if both buttons are pressed simultaneously for 5 seconds. This option can be used to test if the alarm is correctly detected by a receiving system.
- 'Reset alarm' will manually clear all alarms, if both buttons are pressed simultaneously for 5 seconds.

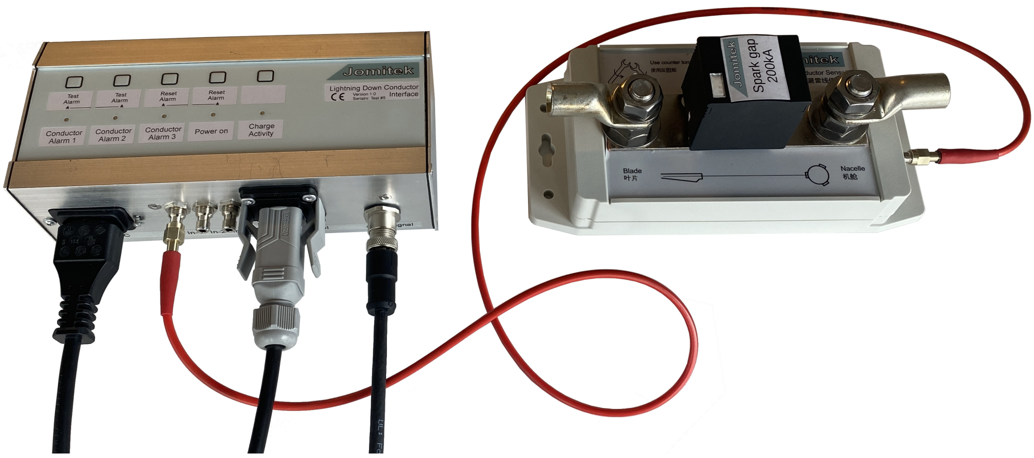

Figure 3: Full system, with one sensor connected, including frontpanel buttons and LED indicators.

1.3 Interface options and requirements in brief

The interface box use an RJ45 Ethernet connector for communication. It may be powered using 230VAC via an IEC C13 connector, or a DC power supply in the range 12-24VDC using the included M12 8-pole connector.

When the sensor is connected via Ethernet, it can be accessed through a web interface, IEC 60870-5-104 protocol, FTP, WebDAV, or a Lua or Telnet client, i.e. using Putty. Additional web service options can easily by tailored to suit SCADA needs, e.g. using JSON-queries to extract sensor status and measurement statistics, etc..

Relay interfacing is supported via an M12 8-pole connector, where 3 wires are dedicated for blade alarm signalling.

1.4 Cyber security considerations

The Jomitek Lightning Down Conductor Sensor uses Ethernet as the medium for communication. The sensor itself is an open device for most of the protocols available. The communication is not encrypted. As such it is strongly recommended to use a firewall protection to critical parts of the turbine Ethernet network.

2 System installation

2.1 Installation prerequisites

A complete Down Conductor Sensor installation will require the following items supplied by Jomitek, of which some are marked optional. Note that it is strongly recommended to specify required cable lengths during ordering, to ease installation efforts.

- 3x sensor boxes - which include 2x M12 attachment points, as well as washers and nuts for these
- 1x interface box - which include all applicable blind plugs
- 3x preassembled fibers numbered 1,2,3 - default length 5m
- Optional: IEC C13 230VAC power cable - default length 3m, and delivered with a mains connector relevant for the region
- Optional: M12 8-pole cable - default length 5m, no connector at the other end (screw terminals, or similar to be used)
- Optional: IP-68 Ethernet cable - default length 5m, with IP-68 connector at one end, and normal RJ45 at the other end
- Optional: Down Conductor Sensor Tester, self contained unit powered by a 9V battery, one unit per installation crew

Additional items that are likely needed include DIN rails, cable shields, clips or similar for cable routing, custom mounting brackets, cable lugs, and equipment needed for terminating either of the optional cables.

2.2 Interface box installation

The interface box support DIN rail mounting on the backside. The point of installation should be selected to accommodate cable routing needs for inputs and outputs, as well as ease of mechanical attachment, and first and foremost to prevent safety hazards.

The fiber routed from each sensor box must be connected to the respective input on the interface box, where it is recommended to ensure a logical match between the blade designation (typically, 1, 2, 3 or A, B, C), with the inputs 1, 2, 3 on the interface box.

Note that the Ethernet port on the interface box must be sealed at all times, either by a termination plug, or by a matched IP-68 Ethernet cable. Similarly for the M12 8-pole connector.

Sensor-to-interface box fibers

A single fiber per sensor box is routed to the relevant interface box input. Test of each installed fiber is recommended, to ensure that the fiber has not been damaged during installation. Let the fiber be connected to the interface box, the interface box must be powered, and then use a flash light, e.g. from a cell phone, to wave in front of the other end of the fiber (disconnect it from the sensor box, if needed). The 'Charge Activity' LED should light up on the interface box. Do this independently for each sensor box, i.e. make sure that the other sensors are disconnected from the fiber during testing. In extension to test of the fiber itself, it is recommended to make an end-to-end test for each box, see the end of 2.3. At the completion of the tests, make sure that all sensors are reconnected to the interface box.

230VAC IEC C13 connection

The 230VAC connection is only a requirement in the case where power is not supplied via other means.

Ethernet connection

The Ethernet connection may be used to support all high level forms of communication with the interface box, including web services, FTP, WebDAV, MODBUS and IEC-60870-5-104. These protocols are primarily intended for measurement readout, but will also enable firmware, software and any settings update after the time of installation.

If Ethernet is targeted as the primary interface, Jomitek may on request include PoE support, which would reduce the connectivity need outside of the sensor system itself, to a single cable.

M12 8-pole connection

The 8-pole connector supports low level relay interfacing with alarm indication for each of the three sensors (blades) separately, as well as a 12-24VDC power supply option. The pin / wire assignments are as follows:

1. Power failure indication (Hi-Z when failure, 0 when OK)
2. Blade 1 alarm (Hi-Z when inactive, 0 when alarm)
3. Common (all input and output relay signals)
4. Alarm reset (Hi-Z when inactive, 0 when resetting)
5. Blade 2 alarm (Hi-Z when inactive, 0 when alarm)
6. Blade 3 alarm (Hi-Z when inactive, 0 when alarm)
7. 12-24VDC (+/-)
8. 12-24VDC (-/+)

After completed installation of the interface box, it is recommended to test that the selected external interfacing via relay and/or Ethernet is operational, by simultaneously pressing the 'Test alarm' buttons for 5 seconds, and verifying that the alarm indication is picked up on the receiving end (turbine control, or parallel monitoring system).

2.3 Sensor box installation

Installation of the Down Conductor Sensor devices require no calibration and no power supply. However it may require a custom mounting solution specific to the wind turbine model. A sensor unit is placed in the area where the blade root attaches to the hub, for each of the blades. The down conductor coming from the blade must be disconnected from the hub ground connection, and attached to the end of the sensor box M12 connection marked with a blade symbol. Similar for the opposite end of the box, an M12 connection must be attached to the hub itself. The intent is to securely fasten the Down Conductor Sensor from a mechanical viewpoint, and from an electrical viewpoint to insert each sensor box in series with the down conductor electrical connection to ground. To prevent safety hazards, this work should be performed when the weather presents no risk of lightning occurring. To prevent a static voltage potential from building up on the blade, the blade down conductor should be temporarily short circuited to the hub ground, as a parallel connection, while the Down Conductor Sensor is being installed. Car starter cables may be a practical solution to accommodate for this. When the sensor box is installed, make sure to remove the parallel connection again. The sensor itself will ensure that the voltage potential between blade and hub, under normal operation, never exceeds 50V.

To ensure proper mounting to the M12 attachment points, the following instructions must be applied: The connecting down conductor cables from the blade and hub side must be equipped with a terminating cable lug with a through hole allowing for secure mounting onto an M12 bolt. The cable lug is placed between nuts and washers, in a symmetrical layer of nut->washer->cable lug->washer->nut. The bottom M12 nut of these layers is held tight by a 19mm wrench, with the aim of providing counter torque. While applying counter torque to the bottom nut, the top nut is then tightened with a 19mm torque wrench according to the specification required by the cable lug manufacturer. This torque must never exceed 50Nm, and will for an appropriately sized cable lug most often be specified in the 25-40Nm range.

Jomitek offer free consultation and/or a design review for the mechanical and electrical interface solution for the sensors. Beside a mechanically secure design, a key focus is to create as much electrical separation as possible between the sensor box, and the electric potential of the down conductor coming from the blade. This means keeping a physical distance of at least 30mm from the box with any conducting material that is part of, or attached to, the blade down conductor. The only exception being the wire or rod connecting to the M12 connection on the sensor box.

Such a design approach will ensure that the sensor box electronics is truly inserted in a series electrical connection between the down conductor, and the hub ground connection. Also, it will promote sustained functionality after a lightning strike, as a lightning discharge is then very unlikely to physically damage the sensor box via unintended arcing outside of the spark gap.

The fiber connnection from each sensor box must be securely attached, shielded from physical impact damage, and otherwise mounted such that it presents no safety hazard. Bending radii of less than 50mm must be avoided.

While each sensor unit is tested and verified functional from the factory, it is recommended to perform an end-to-end test when sensor boxes and the interface box are finally mounted, and the interface box is powered. This is done using the Down Conductor Sensor Tester, which is applied to the screw terminals at each end of the sensor unit to be tested.

- The tester feature a 1Mohm output impedance, with an 80V output, i.e. a maximum short circuit current of 80uA, which ensures that personal safety is not a concern.
- When applied and activated, the tester will make the sensor box generate light pulses, which will cause the 'Charge activity' indicator on the interface box to light up during a successful test.
- If a test is not successful, verify using an Ohmmeter that the resistance across the sensor box terminals is >10kOhm (usually >100kOhm), recheck the fiber connection, and that the interface box has power. If all of these are in order, the sensor is likely damaged and must be replaced.

At the successful conclusion of tests of all 3 sensors, the Jomitek Lightning Down Conductor Sensor system is fully verified and operational.

3 Sensor measurement principle and output options

3.1 Theory of operation

Under open air conditions, an electric potential averaging around 100V/m exists in the atmosphere near the surface of the earth - see https://en.wikipedia.org/wiki/Atmospheric_electricity. The Jomitek Lightning Down Conductor Sensor is specifically designed to make use of this electric potential difference, to detect a relative difference in the effective area/length of the lightning down conductors across the blades of the same wind turbine.

When a blade rotate around the hub, it creates an electric potential equilibrium along the length of the down conductor by soaking up ions / charge build up in the surrounding atmosphere, and carry this charge to ground via the down conductors connection to ground potential. If parts of the down conductor is no longer electrically connected to the hub (ground potential), a lower amount of charge will flow, compared to healthy blades. This characteristic enable detection of partially or fully disconnected down conductors in a wind turbine.

Since there are periods (hours, some times days) when the atmospheric conditions do not present sufficient electric field to provide accurate measurements, the detection method is not instantaneous. The interface box record the measurement data generated by each sensor box continuously. Based on a sufficiently large valid data set, the interface box will then present an alarm if a blade exhibits a lower ability to draw in electrical charge compared to a healthy blade of the same turbine.

During precipitation (rain, hail, snow, etc.), the electric potential fairly high in the atmosphere effectively falls down to ground, captured in the water. This create a dramatically higher charge flow than normal, when the potential difference of the water particles are equalized on the surface of the blade. The volume of water, and how fast it has fallen, is approximately proportional to the severity of precipitation, in terms of the level of wear subjected to the leading edges of the turbine blades. This enable detection of precipitation, graded in to severity levels, with the ability to react within seconds of the onset of heavy precipitation, or a slightly more delayed response in case of a gradual build up, e.g. with snow or fine rain droplets.

3.2 System testing

For basic testing of connectivity, and functionality of the interface box, please refer to 1.2 and 2. Stand alone (lab) testing of the sensors ideally require a setup capable of emulating real world atmospheric conditions as they are subjected to an actual wind turbine blade. As such, end-to-end testing is not trivial due to the nature of the input during normal operation not being well defined, nor straight forward to generate.

A sensor box will generate light pulses with a frequency scaled linearly with the energy of the input received. It features a minimum input impedance of 100kOhm. When the voltage across the terminals exceed 40V and an average current flow of 0.5-1uA, it will start to generate light pulses on the optical output.

A simplified test for verifying the sensor box specifications can therefore be achieved using a voltage source, DC or AC, in series with a high voltage resistor - e.g. from 1Mohm and well into the GOhm-range, where the voltage across the sensor terminals >40V, while the current >1uA.

Applicable examples - either AC RMS or DC - include:

- 80V generator through 1MOhm (max 80uA), this is similar to the Jomitek Down Conductor Sensor Tester
- 230V generator through 10-100MOhm (2.3-23uA)
- 1000V generator through 100MOhm-1GOhm (1-10uA)

Using the web interface of the interface box, it is possible to read out the recorded frequency of the light pulses received from the sensor boxes, in support of such a test campaign.

3.3 Key output parameters

The output parameters, as presented in the Measurements section of the web interface, include 2 main status flags:

- 'alarm' which is a logical OR'ing of alarms from the 3 blades, i.e. if either of the individual blade alarms are triggered, this main alarm indication is triggered as well.
- 'precipitation_warning' equals 0 when no precipitation is detected, with alternate state indications including 1 = light, 2 = medium, 3 = heavy precipitation.

In addition, status indications from the state machine which evaluate the measurements across blades is presented - these show the operational state of the measurement system.

- 'block_valid' indicate that the previous 30 seconds measurement block was valid in terms of sufficient charge being measured.
- 'frame_cnt' is the number of valid measurement frames since last reset.

If the 'frame_cnt' remains 0 after days of normal operation, either the sensors are disconnected or faulty, and should be rechecked with the Down Conductor Sensor Tester, or all 3 blades have disconnected down conductors.

Finally, for the individual blade, the following outputs are available:

- 'alarm' indicate that the blade has a partially or fully disconnected down conductor, based on a significantly reduced ability to gather atmospheric charge, compared to the best performing blade of the turbine.
- 'block_count' is the number of light pulses received in the last 30 second measurement block (30-60 second delay).
- 'pulse_count' is the number of light pulses received during the last 250ms, i.e. a snapshot which can vary widely across the blades.

Any or all of the above mentioned output parameters can easily be mapped to a MODBUS or IEC-60870-5-104 address table, whereas only the basic alarm signal for the individual blades are made available as relay signals. While it may be more simple to interface to the relay signalling, it is strongly recommended to use the Ethernet interface, with supporting protocols. This will support an improved overview of the operational state of the Down Conductor Sensors, and more importantly, the option of reducing wear on the blades via selective slow down of the blade rotation, based on the precipitation warning.

4 Software and firmware structure

4.1 Microcontroller platform and RTOS

The Jomitek Lightning Down Conductor Sensor features powerful embedded hardware especially select and tailored to meet the requirements for stability, redundancy and flexibility. In addition to the powerful computational capabilities, the Jomitek Lightning Down Conductor Sensor features large on-board memory designed for logging during the entire lifetime of the sensor.

The firmware used in the microprocessor can be securely updated over the air using encrypted firmware images, enabling future feature addition and improvements after installation.

The Down Conductor Sensor firmware includes the Lua scripting language which allows for execution of custom code and dynamic reconfiguration of the sensor on the fly. This enables easy integration and customization of live measurements, reports, event summaries, etc. beyond the factory default configuration. Requests for further customization are welcome.

4.2 File system

The Down Conductor Sensor platform features storage of non-volatile data on an eMMC featuring integrated wear leveling. These data include software in the form of Lua scripts and web server content, as well as configuration files and .log files. The eMMC is by default delivered with an 8GB size, which effectively will outlast the lifetime of the sensor and wind turbine.

- `/service` - The main folder containing user relevant data, accessible via FTP or WebDAV, see **??**, **??**.
- `/service/conf` - System configuration files.
- `/service/log` - Sensor log files.
- `/service/software_update` - Folder for uploading firmware and software updates.
- `/service/data` - Measurement data such as log files.

5 Web interface

5.1 General structure

The web interface is structured around four main components as shown in figure 4. The figure is an example from the Jomitek Lightning Sensor and Analyzer, but a similar structure can be found for the Down Conductor Sensor , with the following description:

- The *tab menu* for navigating between sub pages.
- The *main content area* for displaying sub page content.
- The *page context menu* for interacting with the currently selected sub page. This menu may not be available on all sub pages.
- The *notification area* for displaying messages as feedback to user actions and input. Notifications will be queued, with the newest notification appearing at the top of the notification area. Notifications will automatically disappear after 20 seconds, or can be manually dismissed. The notification area displays the SNTP (time synchronization) status in the right hand side. A green light confirms synchronization, while a red indicate no synchronization obtained.

5.2 Sub pages

5.2.1 Explorer view

The *Explorer view* page provides a quick and direct access to most Down Conductor Sensor settings, functions and measurements. All items are arranged in a hierarchical folder structure that can be expanded when clicked.

When a node in the tree is clicked, the *page context menu* will show the node key and value, and if the value is editable, let you enter a new value which can be saved by clicking the *Save value* button.

Depending on the information type, the lowest level expansion will either act as a button executing the relevant command, a link for file download, a link which expands the bottom part of the main page with the requested content, or in case of specific parameter values, the value is inserted in an editable text box.

The **main folder** (top level icon) represents the Down Conductor Sensor sensor device itself, including a few main status and identification parameters. The device text is assembled using the following parameters: The 'type' and 'serial_number' from '*conf/identity.conf*', the MAC address using a special system call and the processor core

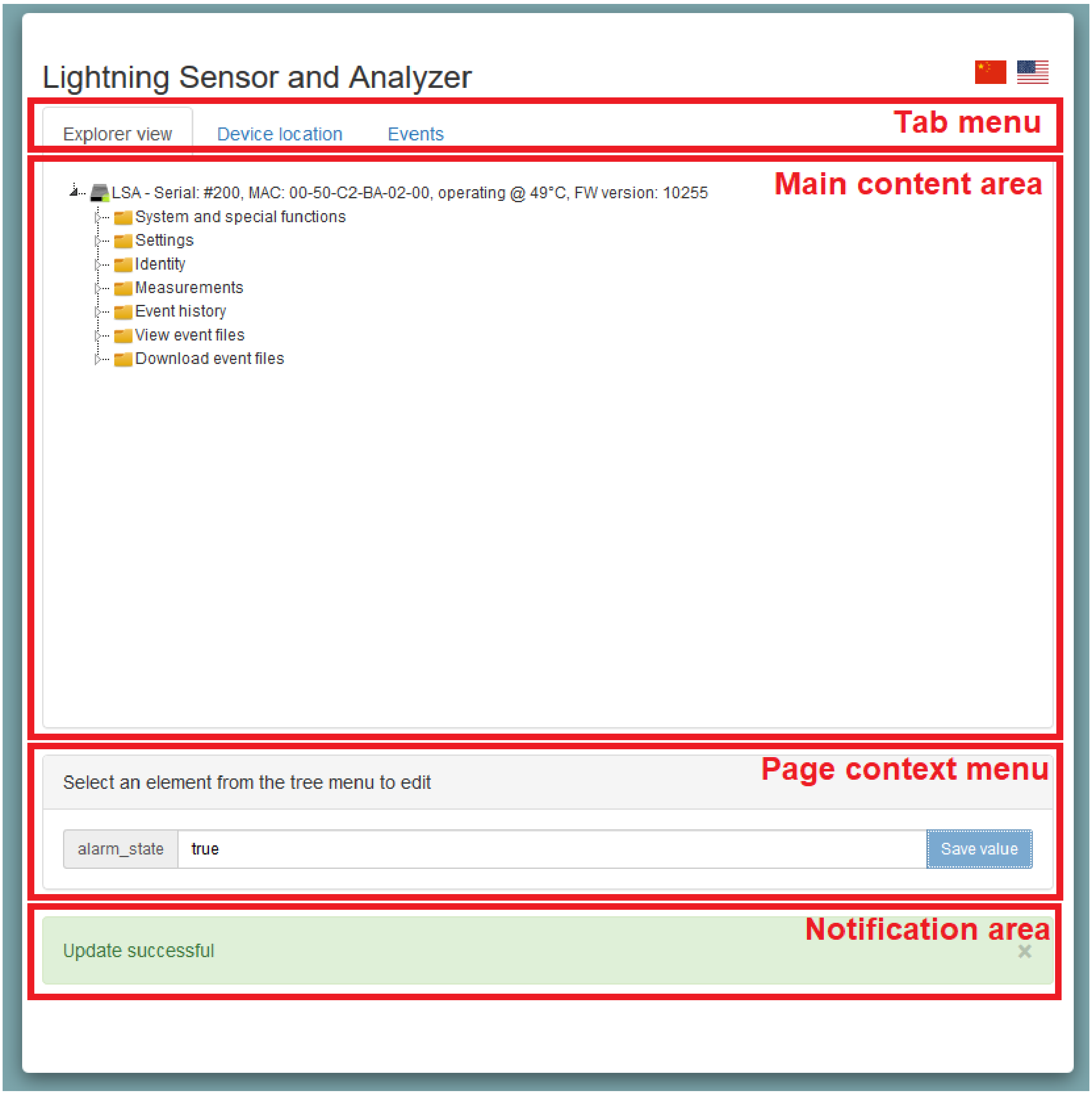

Figure 4: Overview of the web interface showing the layout of the four basic components.

temperature using another system call. When the mouse cursor is positioned on the folder, additional information presenting the server side time of the web page load will occur.

The **Reset and special function** features **Reboot sensor**; A reset command is sent to the sensor, and the web client is set to automatically reload the page when the sensor should be up and running again. If this is not the case, please reload the page again, and remember to check that the IP address targeted is still correct after the reset.

The **Settings** information folder presents a database table as defined by the '*conf/settings.conf*' file. Any web based modication of the parameters will be directly updated in the '*.conf*' file itself. Note that some parameter changes will require a reset to take effect. This folder, along with the **Identity** folder, is a direct mapping of a data table in Lua (in this case 'CONFIG'). This is the reason why there are no special characters, in the subfolder and parameter names. It provides the added benefit, that any modification in the Lua data tables will be directly reflected on the web page at the next reload.

Note that the majority of the parameters in the **Settings** folder are described by placing the cursor above the parameter in question. The same is the case for many of the parameters included in the other folders.

5.2.2 Device location

The *Device location* page visualizes the geographical sensor installation location on an interactive map. The location coordinates can be edited by clicking the map to place a new marker. Once the new mark has been placed at the desired position, the location coordinates can be saved by clicking the *Save coordinates* button in the *page context menu*.

The device location coordinates can also be set through the *Identity/wgs84_coordinate* node in the *Explorer view* sub page.

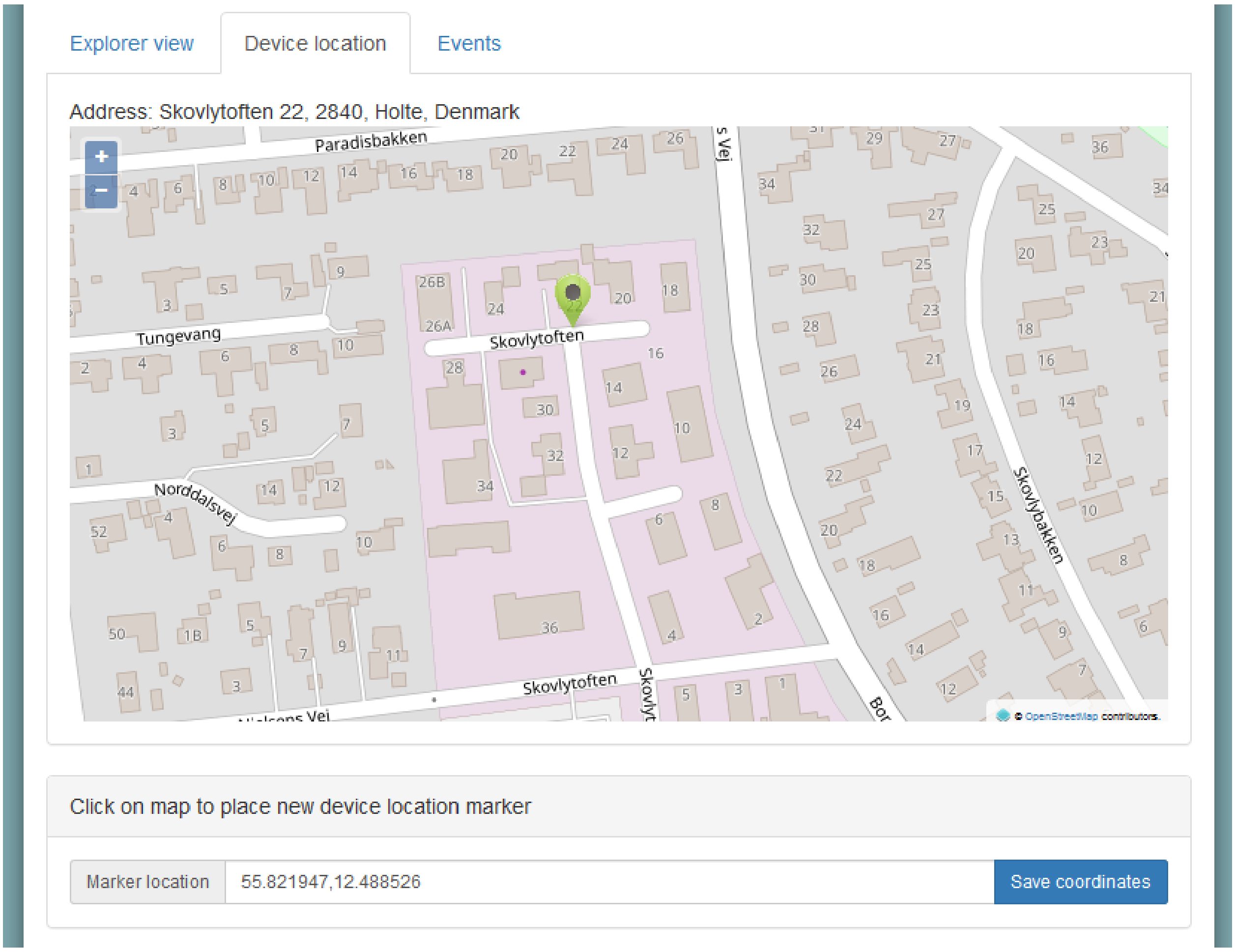

Figure 5: Screen shot from the *Device location* sub page showing the placement of a new marker location ready to be saved.

5.3 Settings

Below is a description of the different subfolders in the settings folder

database
The database subfolder defines a few high level behavior settings for the main Lua data table. It should not be

needed to change these settings under normal circumstances

blade
The blade subfolder contains a number of sensor specific configuration options:

- **alarm_relay** holds the settings for the output alarm relay signal used as an indication to external systems that a down conductor fault has been detected.
- **measurement_configuration** holds configuration parameters related to the alarm detection algorithm, and should only be changed in agreement with Jomitek.

iec104
The iec104 subfolder lists all main parameters used for the IEC 60870-5-104 protocol configuration, including file links used for address mapping and type definition of parameters.

logging
Logging provides parametrization options for what event or error types should be put into the system log. See also the /log folder via FTP. In general, it should not be needed to change these settings. For the Down Conductor Sensor there is also an option to enable/disable logging of time series pulse count data, by setting the log_pulse_count_to_csv to true or false. When set to true, data will be logged in the service/data folder, with historic logs kept in the service/data/pulse_count folder, accessible via FTP or WebDAV.

TCP/IP and NTP
The tcpip setting provides configuration of TCP/IP and (S)NTP settings. The following parameters are available, see figure 6.

- ***dhcp*** a boolean flag for enabling/disabling DHCP in the device.
- ***gateway*** The forwarding host e.g. router to other networks used when no other route specification matches the destination IP address of a packet.
- ***hostname*** The hostname of this device.
- ***icmp*** a boolean flag for enabling/disabling the ICMP ping utility for the device.
- ***ipv4*** the ipv4 address of the device when the sensor is booted with the DHCP flag set to false.
- ***ntpserver*** the ipv4 address of the primary ntp server when the DHCP flag set to false, set ntpserver to 0.0.0.0 to disable.
- ***ntpserver_alt*** the ipv4 address of the secondary ntp server when the DHCP flag set to false, the ntpserver_alt address is only used when the ntpserver addess is not 0.0.0.0, set ntpserver_alt to 0.0.0.0 to disable.
- ***subnet*** the subnet mask used when the sensor is booted with the DHCP flag set to false.

The sensor supports SNTP in two ways: By default when the DHCP flag is set to true, the sensor queries the DHCP server for an NTP server address. When the DHCP flag is set to false, or the DHCP server does not respond with an NTP server address, the sensor rely on the user to provide a set of valid NTP server addresses. These addresses are to be typed into the ntpserver and ntpserver_alt fields. For wind turbine farms, an NTP server is often present locally which would then be the preferred source, and otherwise public NTP servers may be used.

As a default DHCP is set to true. The IP and gateway address and the subnet mask is also defined here and is only used when the sensor is booted with the DHCP flag set to false. Note that if the device experiences severe errors during startup, it will revert to the IP configuration defined in the '*conf/panic.ip*' file, and if this also fail to load, the following hardcoded settings will be used: dhcp=false, gateway=192.168.135.100, ipv4=192.168.135.18, subnet=255.255.255.0. In DHCP mode, in the case where no DHCP server can be reached, the sensor will automatically choose a random IP address in the range 169.254.1.0 to 169.254.254.255 in compliance with RFC 3927 Section 2.1.

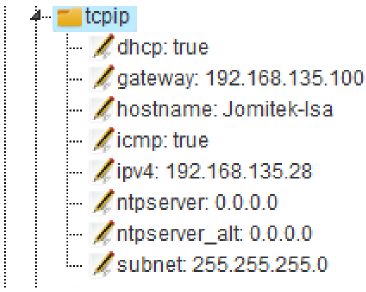

Figure 6: Overview of the web interface showing the TCP/IP settings.

timezone
The timezone settings can be found in the **time** folder.

- ***dst*** a **true/false** flag for enabling/disabling daylight saving time.
- ***utc_offset_hh*** sets the time offset with reference to UTC in hours west of Greenwich.
- ***utc_offset_mm*** sets the time offset with reference to UTC in minutes west of Greenwich.

web
The parameters in the web section defines which port is used for the web service (default is ’80’), and the file path for the description file used to link in (a) basic parameter validation via the web interface (’boolean’, ’integer’, ’float’, ’string’, ’ipv4’), and (b) description text when mouse cursor is above the parameter in question.

Identity
The Identity folder contains all the location and naming related information for a specific device. It should always be edited, or generated, on an individual basis. The parameters include address, city, zip, country_state, location_name and location_description as identifying text for the location. The location_name could e.g. be the name or reference for a wind turbine, and the location_description could detail the wind turbine park name. Furthermore the location may be specified using WGS84 coordinates in a ’<latitude>,<longitude>’ decimal degrees format. The serial_number may be set to match the Jomitek device serial number, or a custom format defined by the operator. In this context, note that the only hardcoded identifier of a device is the uniquely assigned MAC address. The type parameter will, if left blank, be automatically set during bootup based on a device internal check of the accessible peripherals. Custom naming may be used as an alternative.

6 IEC-60870-5-104 configuration

The IEC 60870-5-104 (abbreviated "IEC 104" or "104" in the following) application layer protocol can be used for transmitting sensor data from the sensor to a SCADA system or another data-aggregation device implementing the IEC 104 protocol. The TCP/IP protocol suite is used to ensure reliable data transfer. Additionally, the 104 protocol supports message sequencing on the application layer. A 104 client connects to the IANA assigned TCP port 2404.

The sensor allows flexible configuration of the protocol settings, and of the data points. The data points can be transmitted based on a variety of triggers, including on-change, periodic, on manual request, or using interrogation commands requesting a larger set of data. The sensor can be configured to use all features defined in the IEC 104 standard, or the sensor can use a small subset for simpler applications.

The 104 protocol settings are found in the settings.conf file under the "iec104" section. These shall match the protocol settings defined in the SCADA client, and must be in compliance with the IEC standard. Interoperability requirements can be documented by a 104 client by filling out Chapter 9 in the IEC 104 standard. An overview of the parameters defined in the sensor are listed in table 1.

Setting	**Meaning**	**Default**
t1	Time-out of send or test APDUs.	16
t2	Time-out for acknowledges in case of no data messages, t2<t1.	11
t3	Time-out for sending test frames in case of a long idle state.	21
k	Maximum difference receive sequence number to send state variable.	8
w	Latest acknowledge after receive w I format APDUs.	12
common_address	IEC 104 address of sensor.	1
background_scan	Interval in seconds between transmission of digital data points.	1800
cyclic	Interval in seconds between transmission of analogue data points.	600
scan	Data change scan interval in milliseconds for sending event-triggered data.	500
clock_validity	Time-tagged client commands validity period in seconds.	600
redundancy	Max number of redundant connections as defined by IEC 104.	2

Table 1: IEC-104 parameters.

Three *.csv* files are used to map internal sensor measurements to data points accessible by an IEC 104 client. A macro enabled Excel file is used to generate these *.csv* files, and all changes to the data mapping should be applied in the Excel file. There are three sheets in the Excel file, and each generate one .csv file. The sheets are called "iec104_analogue", "iec104_digital" and "iec104_commands", which define analogue and digital measurement mapping to the IEC 104 protocol. An example snapshot of the "iec104_analogue" sheet is shown in figure 7.

address	type	data	interrogation	spontaneous	cyclic	absmin	absmax	rel	interval	desc
5000	M_ME_TF_1	measurements.alarm	global	true	true	0	0	0	0	General alarm: One or more blades with damaged down conductor
5001	M_ME_TF_1	measurements.blade_1.alarm	global	true	true	0	0	0	0	Alarm: Damaged down conductor on blade 1
5002	M_ME_TF_1	measurements.blade_2.alarm	global	true	true	0	0	0	0	Alarm: Damaged down conductor on blade 2
5003	M_ME_TF_1	measurements.blade_1.alarm	global	true	true	0	0	0	0	Alarm: Damaged down conductor on blade 3
5010	M_ME_TE_1	measurements.precipitation_warning	global	true	true	0	0	0	0	Precipitation warning: 0=No precip -- 1=light -- 2=medium -- 3=heavy

Figure 7: iec104_analogue.

Description of columns:

- **address** The address of the data point, [1-65535].
- **type** The IEC 104 type (see interoperability list in IEC 60870-5-104 chapter 9).
- **data** Internal sensor variable name.
- **interrogation** The interrogation group this data point belongs to. Can be "global" or "groupX" where X is in the range [1-16].

- **spontaneous** Set to true if data point should be transmitted on change.
- **cyclic** Set to true if data point should be sent periodically.
- **absmin** Minimum absolute change in data value to trigger spontaneous transmission. This is useful for avoiding sending a data point too often when the value is low.
- **absmax** Maximum absolute change in data value to trigger spontaneous transmission.
- **rel** Relative change in percent of the data value to trigger spontaneous transmission. For example, setting rel = 10 for a data point with value 500 triggers transmission at 450 or 550.
- **desc** A short description of the data point and unit. The description will be used as a tooltip in the web interface.

Refer to figure 8 for a graphical example of the transmission thresholds absmin, absmax and rel.

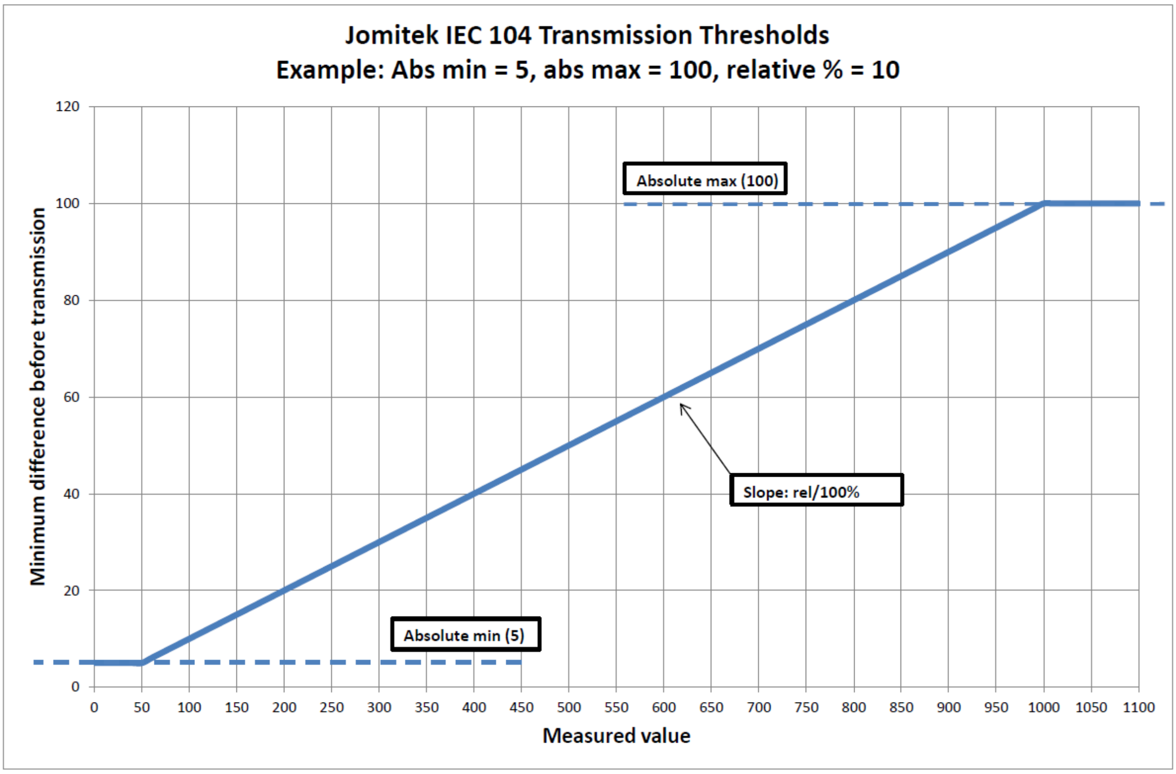

Figure 8: absmin, absmax and rel.

Any change in a digital value triggers transmission given spontaneous is set true for this data point in the "iec104_digital" sheet. For this reason the "iec104_digital" sheet does not define absmin, absmax and rel columns. Also, the "iec104_digital" sheet replaces the "cyclic" column found in the analogue sheet with "background". The use of the "cyclic" column for analogue values is similar to the use of "background" column because they are both used to trigger transmission at fixed intervals.

Additionally, all IEC 104 commands are supported by the sensor, and they can be used to invoke any function or define any setting in the sensor as desired. However, depending on the application and due to the variety of protocols supported by the sensor, IEC 104 commands may not be needed. The "iec104_commands" sheet in the Excel file map a data point address to an internal variable.

Since the IEC 104 protocol uses TCP/IP, it is in some cases useful to debug the communication stream using Wireshark[1].

[1] https://www.wireshark.org/

7 MODBUS configuration

As an alternative to communication via the IEC 60870-5-104 protocol, MODBUS TCP is also supported, using the default addressing specification found in table 2:

Description	Unit	Range	Address	MODBUS function code
Software version	Number	0-65535	0	4 (read)
Serial number	Number	0-65535	1	4 (read)
Alarm status	Boolean (1=alarm)	0-1	5000	4 (read), 6 (write)
Blade 1 alarm status	Boolean (1=alarm)	0-1	5001	4 (read)
Blade 2 alarm status	Boolean (1=alarm)	0-1	5002	4 (read)
Blade 3 alarm status	Boolean (1=alarm)	0-1	5003	4 (read)
Precipitation warning	Number	0-3	5010	4 (read)
Block valid	Boolean (1=valid)	0-1	6000	4 (read)
Frame count	Number	0-65535	6001	4 (read)
Block count blade 1	Number	0-65535	6011	4 (read)
Block count blade 2	Number	0-65535	6012	4 (read)
Block count blade 3	Number	0-65535	6013	4 (read)
Pulse count blade 1	Number	0-65535	6021	4 (read)
Pulse count blade 2	Number	0-65535	6022	4 (read)
Pulse count blade 3	Number	0-65535	6023	4 (read)

Table 2: MODBUS address table

Note that the 'magic number' for clearing an alarm requires writing 0x4341 (17217 decimal) to address 5000.

Alternative function codes

Alternative for function code 4 (read register) is function code 3. They are implemented in an equal way. Alternative for function code 6 (write single register), is function code 16 (write multiple registers) and then just specifying a single register in the command.

8 Firmware and software updates

8.1 Boot loading sequence

During startup the Down Conductor Sensor checks the `/service/software_update` folder for the presence of a **software update file** or **firmware image file**.

- A **software update file** (`software.tar.gz`) contains a folder structure image that, when unpacked, overwrites the in-place file-system. The unpacked file-system may include a **firmware image file** in the software update folder.
- A **firmware image file** (`image.bin`) is a binary file which contains the most basic low-level software needed to run the Down Conductor Sensor device.

If a **software update file** is found, it is unpacked and installed automatically, during the next sensor reboot. Such a reboot will therefore often take 2-3 minutes, compared with a standard reboot time of approximately 30 seconds.

If a **firmware image file** is found, the boot loader will search for the presence of a **checksum file** (`checksum.txt`) which is used to verify the integrity of the firmware image. If the calculated checksums match, the firmware is decrypted and its binary instructions copied to the microprocessor which will reboot upon completion, thus finalizing the firmware update process. This process ensures all firmware updates are end-to-end secure, and only updates issued by Jomitek will be possible to load.

After boot loading completes, the system will proceed to initiate further low-level processes after which the Lua scripting engine and web server will be started. At this point the system will be fully operational.

8.2 Firmware upgrade

The software or firmware on the Down Conductor Sensor can be updated in four simple steps:

1. Download the newest update file from `http://jomitek.dk/downloads/device_software_update`. The page is password protected, use username: *jomitek* and password: *jomitek*.
2. Connect to the Down Conductor Sensor through the FTP interface with username: *service* and password: *service1234*.
3. Transfer the update file, `software.tar.gz`, to the `/service/software_update` directory.
4. Reboot the Down Conductor Sensor through the web interface and wait for the boot loading sequence to automatically apply the update.

The Down Conductor Sensor will now restart and apply the software update.

For automated mass updates, please refer to `http://jomitek.dk/downloads/tools`, where an Excel and WinSCP-based tool is provided for reference. The mass updates are based purely on WebDAV, i.e. default port 80, which should help avoid many issues in relation to firewall configurations, and related security bottlenecks. Other scripting and file transfer tools may be used based on the example provided.

9 Advanced user interfaces

9.1 Telnet command line interface

For advanced maintenance and debugging tasks, the Down Conductor Sensor can be accessed and configured via a limited command line interface using Telnet. This interface is accessed by connecting to the sensor IP address on TCP port 23 using a standard Telnet client. It is recommended to use Putty[2] which is open source and free to use.

Be sure to enable the 'Implicit CR in every LF' and 'Implicit LF in every CR' options when configuring Putty.

A list of applicable Telnet commands for the Down Conductor Sensor is listed by typing 'help' in a Telnet terminal, when connected to a sensor.

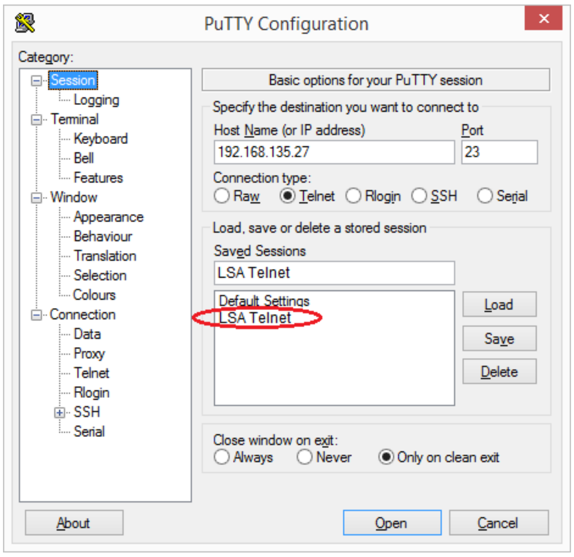

Figure 9: Putty Telnet Session configuration.

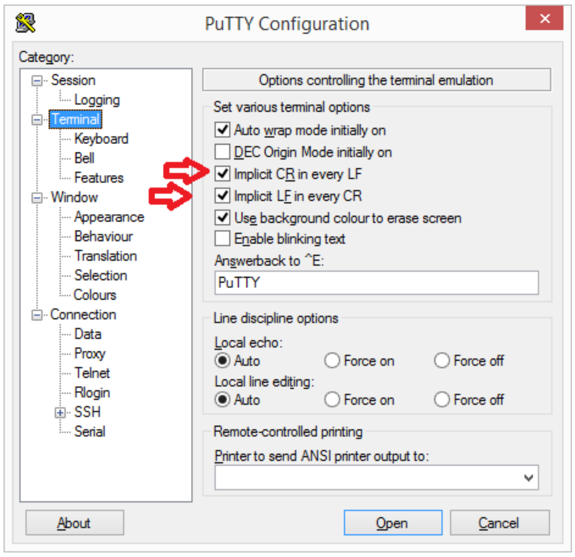

Figure 10: Putty Telnet Terminal configuration.

For use for software interface test, it is possible to issue a trig command that brings an alarm through the sensor, just without collecting data. The command is 'trig' via Telnet.

9.2 FTP file transfer interface

The internal memory on the Down Conductor Sensor can be accessed via the FTP protocol on TCP port 21. Use an FTP client program (e.g. FileZilla[3]) and log in with default username: *service* and password: *service1234*.

When connected you will have access to these folders.

- The `software_update` folder where software update files can be uploaded.
- The `log` folder where various log files are placed by the sensor system.
- The `conf` folder where configuration files and scripts are stored.

[2] `http://www.putty.org/`
[3] `https://filezilla-project.org/`

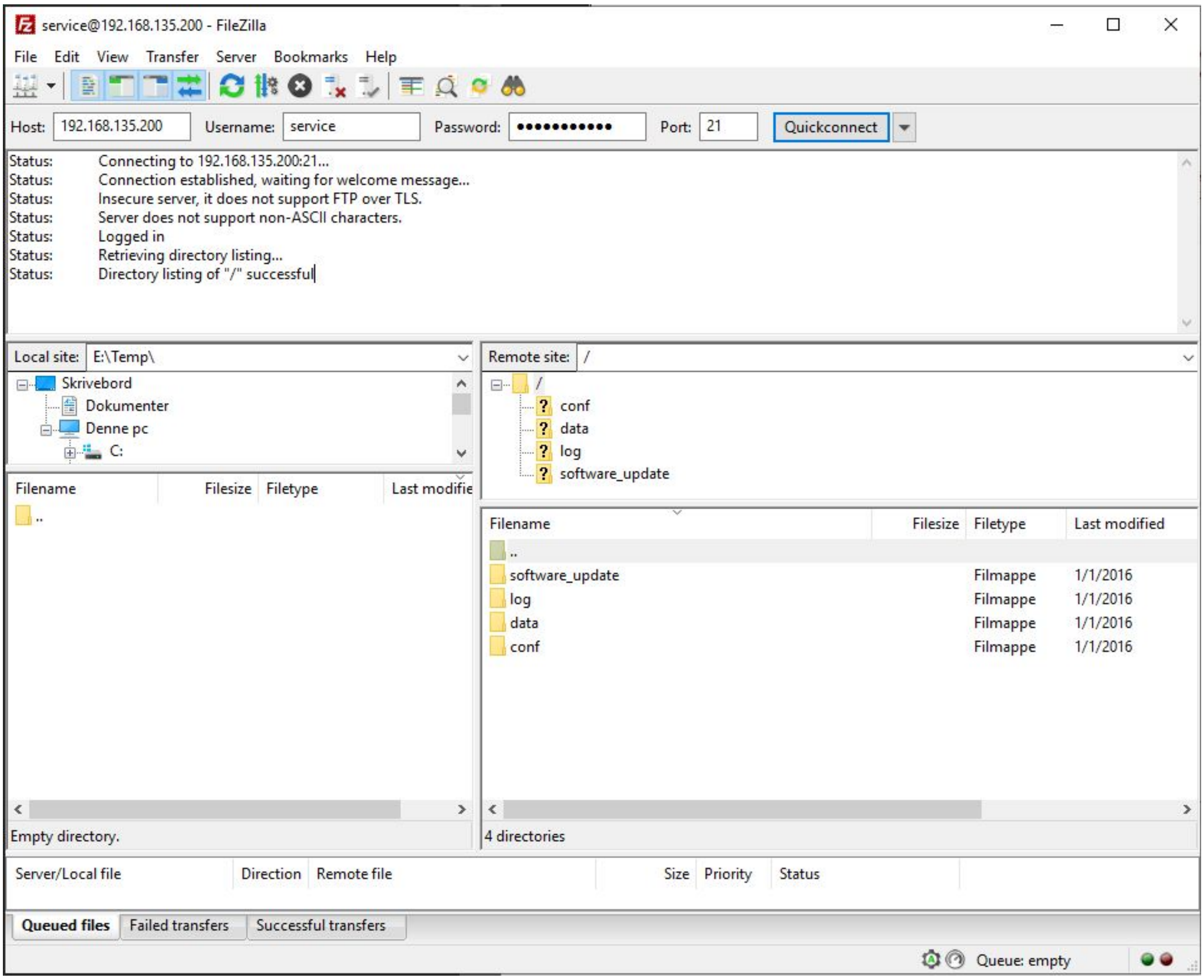

Figure 11: FTP connection to the Down Conductor Sensor shown with the FileZilla FTP client.

File Upload is supporting upload one file at a time, so set the sender to non-simultaneous file-transfer.

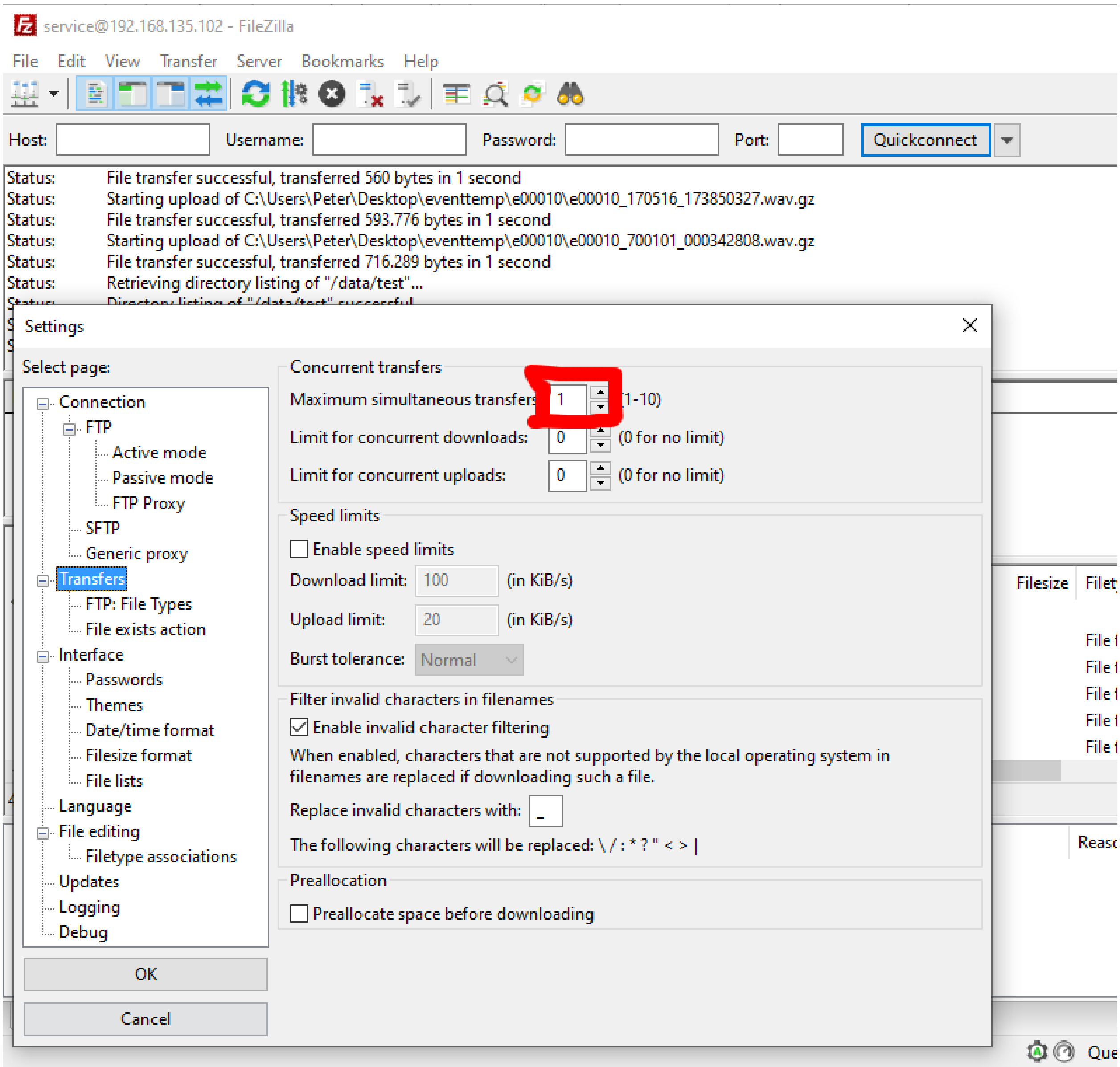

Figure 12: FTP configuration for file upload via FileZilla.

9.3 WebDAV file transfer interface

The internal memory on the Down Conductor Sensor can be accessed via the webDAV protocol on TCP port 80. This gives the advantage that it uses the same port as a normal internet browser and thereby makes firewall setup easy. Use a webDAV client program (e.g. WinSCP) and log in with default username: *service* and password: *service1234*.

Connect to the subfolder '/dav' as shown in the figure.

The files to access are the same as described in the chapter 'FTP file transfer' 9.2.

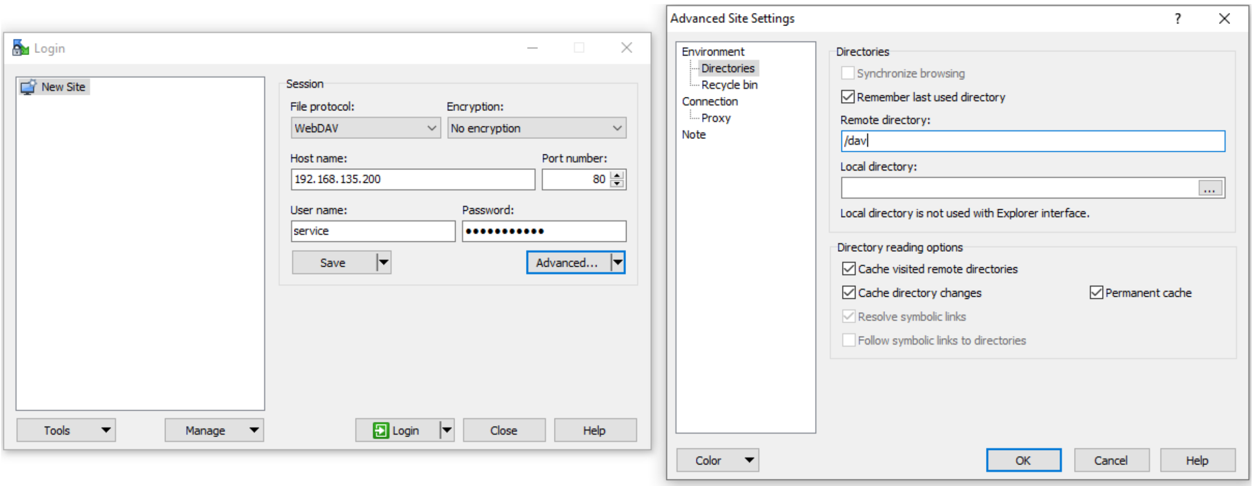

Figure 13: webDAV connection to the Down Conductor Sensor shown with the WinSCP client.