



Wind Turbine Controller

Technical Manual

Product description · Supported turbine controllers · Installation · User guide

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Smart Tech Innovation S.R.L.

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About this document

This manual describes the **WindCtrl** wind turbine controller developed by Smart Tech Innovation S.R.L. It covers the product architecture, the supported turbine control systems, physical installation and commissioning, and day-to-day operation through the WindCtrl web interface.

Intended audience

The manual is written for technical personnel: electrical and automation engineers, wind farm service technicians, SCADA integrators and asset operators. Readers are expected to be familiar with low-voltage control cabinets, serial (RS-232 / RS-485) and Ethernet field networks, and the operating principles of grid-connected wind turbines.

Scope

- Applies to the WindCtrl turbine controller on the CM4 industrial hardware platform, firmware generation 1.x.
- The device is intended to monitor and control various models of wind turbines to control at one point.
- Screens and menu names may change slightly between firmware releases. The functional behaviour described here remains valid unless stated otherwise in the release notes.

Revision history

Revision	Date	Description
1.0	October 2026	First release of the technical manual.

Conventions

Convention	Meaning
Bold	User interface elements: page names, buttons, fields.
Monospace	Values to enter, interface names, file or device names.
WARNING	Risk of personal injury or damage to the turbine.
CAUTION	Risk of malfunction, loss of data or incorrect operation.
NOTE / TIP	Additional information and good practice.

1. Safety information

WARNING — Remote control of rotating machinery

WindCtrl can start, stop, reset and curtail a wind turbine remotely. Before issuing any command, make sure that nobody is working in or on the turbine and that local operating procedures permit remote operation.

- Installation, wiring and commissioning must be carried out only by qualified electricians or service technicians authorised by the turbine owner.
- De-energise the control cabinet and apply lock-out / tag-out before connecting or disconnecting WindCtrl. Observe the turbine manufacturer's safety instructions at all times.
- WindCtrl is a supervisory and remote-control device. It is **not** part of the turbine safety chain and must never be used as an emergency stop, overspeed protection or grid protection device. The turbine's own safety system always has priority.
- Commands sent through WindCtrl are executed by the turbine controller according to its own logic and interlocks. A command accepted by WindCtrl is not a guarantee that the turbine will change state; always confirm the result on the status display.
- Use only shielded, twisted-pair cable for serial links and keep signal cables separated from power cables inside the cabinet.
- Keep the device credentials confidential. Change default passwords at commissioning and restrict network access to the controller (see Chapter 9).

CAUTION — Grid support functions

Reactive power / voltage support (Chapter 8) changes the behaviour of the turbine at the point of connection. Enable it only when required by the grid operator and after the characteristic has been agreed and verified.

2. Product description

2.1 What WindCtrl is

WindCtrl is an industrial controller that is installed inside the control cabinet of an existing wind turbine. It connects to the turbine's original controller through the remote-monitoring or service interface the manufacturer provides, translates the manufacturer-specific data into one unified data model, and makes the turbine visible and controllable through a modern web interface, a dispatch / SCADA link and a central fleet-monitoring platform.

WindCtrl is designed for the retrofit market: older turbines whose original remote-monitoring systems are obsolete, unsupported or no longer reachable. It gives every supported turbine – regardless of manufacturer or age – the same screens, the same alarm handling, the same statistics and the same remote-control functions.

2.2 Key benefits

- **One interface for a mixed fleet** – Enercon, Mita-Teknik WP3000 based turbines (Micon, Nordex, REpower, Fuhrländer, DeWind, Suzlon and others), GE Wind, Vestas and Nordex/Phoenix Contact controllers are presented identically.
- **Local first** – the controller runs entirely on site. Monitoring, logging and control continue during internet outages; data is buffered locally.
- **Live data** – operating values are refreshed down to one-second intervals depending on the turbine interface.
- **Remote operation** – start, stop, reset and active power limitation (where supported by the turbine controller), from the web interface or from the grid operator's dispatch system.
- **Grid compliance** – voltage-dependent power factor control, Q(U), through an analog set-point output and a grid meter at the point of connection.
- **Full traceability** – every alarm, event and operator command is time-stamped and stored with the user and the channel that issued it.
- **Performance insight** – daily, weekly, monthly and yearly production statistics and an automatically learned power curve.

2.3 System architecture

Figure 1 shows the main functional blocks. The turbine driver layer contains one dedicated driver for each controller family. Each driver polls the turbine, decodes status and alarm codes, and executes commands. All drivers feed the same unified data model, from which the logbooks, statistics, web interface and external links are served.

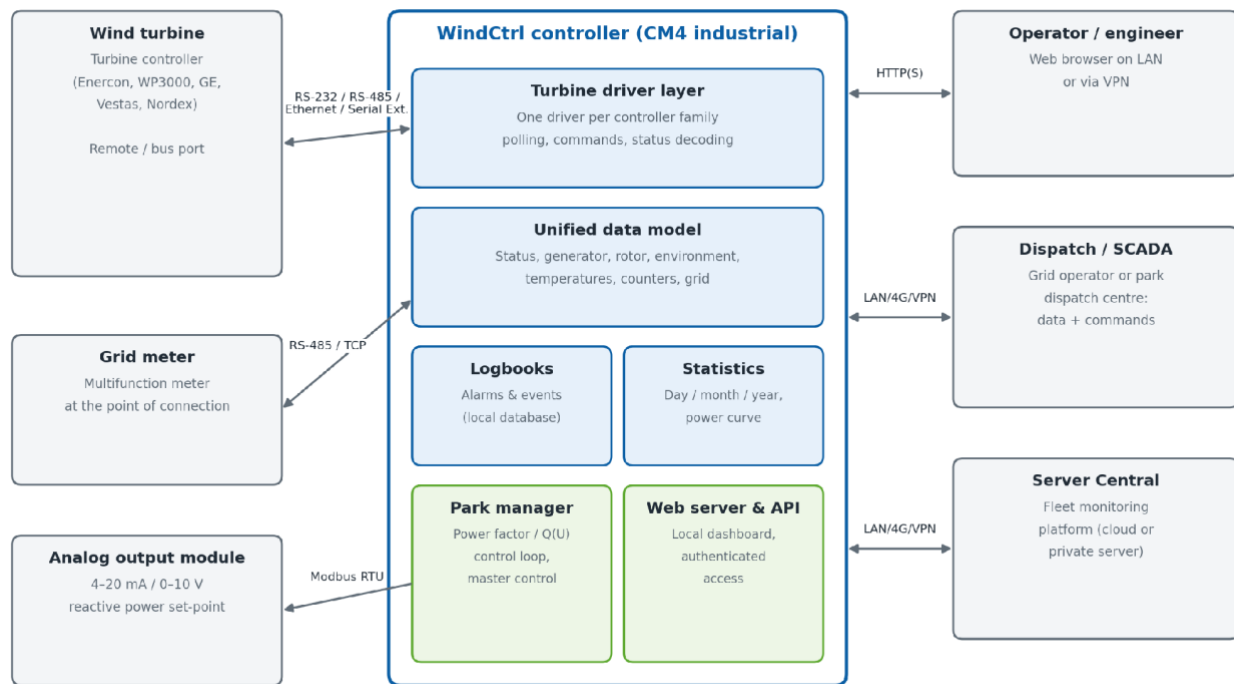


Figure 1. WindCtrl functional architecture

Functional blocks

Block	Function
Turbine driver layer	Manufacturer-specific communication with the turbine controller: cyclic data acquisition, status/alarm decoding, command execution, communication supervision.
Unified data model	Common representation of turbine state, generator, rotor, environment, temperatures, energy counters and grid values, independent of the turbine make.
Logbooks	Persistent alarm log (with acknowledgement) and event log, stored in a local database on the controller. Entries older than one year are purged automatically.
Statistics	Minute-level recording of production and operating values, aggregated into day, week, month and year views. Learns the turbine's real power curve from operating data.
Park manager	Grid-related functions: voltage-dependent power factor set-point, closed-loop control of the reactive power output, park-level command dispatch and master control handling.
Web server & API	Local, password-protected web application used for monitoring, operation and configuration. Also provides a live remote service console for supported controllers.
External links	Dispatch / SCADA link to the grid operator or park dispatch centre and a connection to Server Central, the fleet monitoring platform.

2.4 Software platform

The WindCtrl application is a native C++ service running on a hardened Debian Linux system. It is delivered as a container image, which allows the same firmware to be deployed identically on every unit and to be updated remotely without site visits. Configuration, logbooks and statistics are kept on a persistent data partition and survive firmware updates.

Operating system	Debian Linux (64-bit ARM)
Application	WindCtrl turbine service (C++), containerised
Data storage	Local embedded database for logbooks and statistics; configuration file on persistent storage
User interface	Web application, responsive (desktop, tablet, phone); light/dark theme
Update mechanism	Automatic check for new releases every 5 minutes when online; update applied in place, data preserved
Housekeeping	Weekly automatic cleanup of obsolete images; log rotation; one-year retention of logbooks
Time synchronisation	NTP when online; local time zone configured per site

3. Hardware

WindCtrl runs on an industrial carrier board based on the Raspberry Pi Compute Module 4 (CM4). The unit is DIN-rail mountable and provides all interfaces needed in a turbine control cabinet.

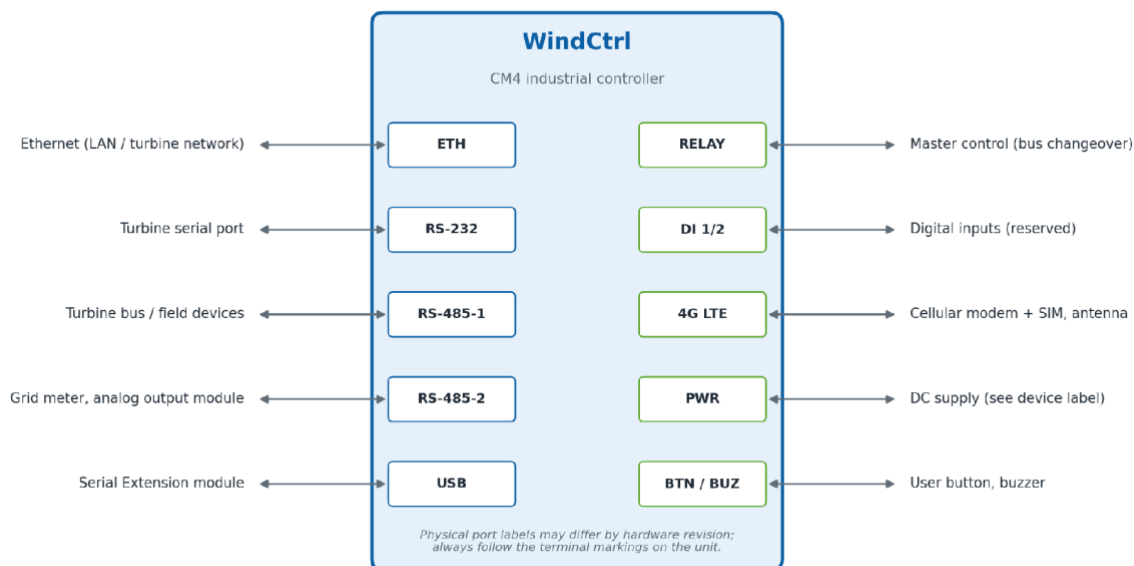


Figure 2. Controller interfaces and their typical use

Table 1. Hardware overview

Device model	CM4-WINDCTRL
Processor	Raspberry Pi Compute Module 4, quad-core 64-bit ARM
Mounting	DIN rail (TS-35), inside the turbine control cabinet
Power supply	Industrial DC supply – voltage range as printed on the device label
Ethernet	1 × 10/100/1000 Mbit/s – site LAN, turbine controller network, Modbus TCP devices
RS-232	1 × – turbine serial service / remote port
RS-485	2 × isolated – turbine field bus, grid meter, analog output module
USB	Host ports – WindCtrl Serial Extension module, service
Relay output	1 × – Master Control (changeover of the turbine communication line)
Digital inputs	2 × – reserved for site-specific functions
Cellular (optional)	4G LTE modem (Quectel EC25 class), micro-SIM, external antenna
Local signalling	Buzzer, user push-button, cooling fan control
Operating temperature	According to the carrier board specification; install away from heat sources

3.1 Interface naming

Interfaces are referred to in the WindCtrl settings by their system names. Use the following names when configuring a communication interface:

Physical interface	Name in settings	Typical use
Ethernet	IP address of the target, e.g. 192.168.100.100	Enercon Modbus, GE Bachmann, Nordex Phoenix, grid meter (TCP)
RS-232	/dev/rs232	Turbine serial ports (e.g. WP3000, Vestas)
RS-485 port 1	/dev/rs485-1	Turbine field bus (e.g. GE Suconet K)
RS-485 port 2	/dev/rs485-2	Grid meter, analog output module
Serial Extension (USB)	/dev/ttyACM0	Enercon serial line (E66 / E70 profiles)

NOTE

The RS-485 ports and the Serial Extension module are shared resources. Several Modbus RTU devices (for example a grid meter and an analog output module) may share one RS-485 port when they use different unit IDs and the same baud rate.

3.2 Accessory modules

Accessory	Purpose
WindCtrl Serial Extension module	USB-connected line adapter that reproduces the electrical characteristics of the original Enercon remote-monitoring line. Required for the Enercon Serial E66 / E70 connection types.
Grid meter (Lovato DMG series)	Multifunction meter at the point of connection, read over Modbus (RTU or TCP). Provides grid voltages, currents, frequency, P, Q, S and power factor. Required for the voltage support function.
Analog output module 4–20 mA	Waveshare Modbus RTU analog output. Drives the reactive power / power factor set-point input of the turbine or converter.
Analog output module 0–10 V	As above, voltage version. Select the variant that matches the set-point input of the turbine.
LTE antenna and SIM	For sites without a wired internet connection. A data SIM with a public or operator-routed IP is needed if the dispatch centre connects to the site over the mobile network.

4. Supported turbine controllers

WindCtrl selects the communication driver from two settings: **Controller Model** (the manufacturer family) and **Communication Type** (the physical and logical interface). Table 2 lists all supported combinations; the following chapters describe each one in detail.

Table 2. Controller model and communication type combinations

Controller model	Communication type	Physical link	Mode
Enercon	Enercon – Modbus	Ethernet	Monitoring + control
Enercon	Enercon – Serial E66	Serial Extension (USB)	Monitoring + control
Enercon	Enercon – Serial E70	Serial Extension (USB)	Monitoring + control
WP3000 – RePower	RePower Serial	RS-232	Monitoring + control + service menu
GE Wind Power	GE Suconet K	RS-485	Monitoring + control
GE Wind Power	GE TCP (Bachmann)	Ethernet	Monitoring
Vestas	Vestas	Serial	Monitoring
Nordex	Phoenix TCP	Ethernet	Monitoring

4.1 Feature matrix

Legend: ● supported, ○ supported with conditions (see the controller chapter), — not supported by this controller interface.

Table 3. Functions available per controller family

Function	Enercon Modbus	Enercon Serial	WP3000	GE Suconet K	GE Bachmann	Vestas	Nordex Phoenix
Live operating data	●	●	●	●	●	●	●
Status & description	●	●	●	●	●	●	●
Temperatures page	●	●	●	—	●	○	●
Energy counters	●	●	●	●	—	—	—
Start / Stop	●	●	●	●	—	—	—
Reset	●	●	●	○	—	—	—
Active power limit	●	●	○	—	—	—	—
Remote service menu	—	—	●	—	—	—	—
Master control relay	—	●	—	●	—	—	—
Learned power curve	●	●	●	●	●	●	●
Statistics	●	●	●	●	●	●	●
Dispatch / SCADA link	●	●	●	●	●	●	●

NOTE

Functions marked — are limited by what the original turbine interface exposes, not by WindCtrl. Monitoring-only drivers are being extended continuously; check the release notes for newly enabled control functions.

4.2 Data common to all drivers

Independently of the turbine make, WindCtrl presents the following groups of values. Values that a particular controller does not provide are shown as empty or zero.

Group	Values
Turbine	Generic state (Active / Inactive / Error), generic status (OK / Warning / Error / Maintenance), manufacturer status code with plain-text description, warning code, operating hours, nacelle position
Generator	Phase voltages U1–U3, phase currents I1–I3, frequency, active / reactive / apparent power, power factor, generator speed, generator and gearbox temperature, energy delivered and consumed, power limit (kW and %) and its source
Rotor	Rotor speed, blade pitch angle
Environment	Wind speed, wind direction, ambient temperature
Temperatures	Up to 45 measuring points depending on the turbine (generator windings and bearings, gearbox, oil, main bearings, nacelle, cabinets, pitch motors and batteries, cooling water, yaw ring, tower...)
Grid (with grid meter)	Line voltages, currents, phase-to-phase voltage, total current, frequency, P, Q, S, power factor
Device	Controller ID, model, firmware and hardware version, uptime, communication state, licence state

5. Turbine controller reference

Each section below describes one controller family: the turbines on which it is typically found, how WindCtrl connects to it, how the driver works and which functions are available. Always verify the actual controller type and interface on site before ordering accessories.

5.1 Enercon

Controller and typical turbines

Enercon turbines (for example the E-40, E-66, E-70 and later generations) use Enercon's own turbine control system. Depending on the age and equipment of the turbine, remote access is available either through an Ethernet SCADA interface with Modbus TCP, or through the original serial remote-monitoring line. WindCtrl supports both.

Communication type	When to use
Enercon – Modbus	Turbine is equipped with an Ethernet SCADA / Modbus TCP interface. Preferred option where available: fastest update rate and simplest wiring.
Enercon – Serial E66	Serial remote-monitoring line, E-66 generation controllers.
Enercon – Serial E70	Serial remote-monitoring line, E-70 and later controllers using the newer line profile (includes a periodic keep-alive).

Connection – Enercon Modbus

1. Connect the WindCtrl **ETH** port to the turbine SCADA network switch or directly to the Modbus interface of the turbine controller.
2. Assign WindCtrl a free IP address in the same subnet as the turbine interface (see 6.4).
3. In **Settings → Communication Settings** enter the turbine interface IP address in **Url / Ip / Interface** and the Modbus port in **Port**; select **Enercon – Modbus**.
4. Set **Controller Model** to **Enercon**, save and reboot.

Connection – Enercon Serial (E66 / E70)

1. Connect the WindCtrl Serial Extension module to a USB port of the controller.
2. Connect the line side of the Serial Extension module to the turbine's remote-monitoring line terminals in parallel with, or instead of, the original remote-monitoring equipment (see Master Control below).
3. If the original remote system must remain connected, wire the Master Control relay so that it switches the line between the original system and WindCtrl.
4. In **Settings → Communication Settings** set **Url / Ip / Interface** to `/dev/ttyACM0` and select **Enercon – Serial E66** or **Enercon – Serial E70**.
5. Set **Controller Model** to **Enercon**, save and reboot. The **Description** field on the dashboard shows the decoded turbine status as soon as communication is established.

Operating principle

- **Modbus**: fast values (power, wind, speed, electrical values) are refreshed every second; slow values every 5 seconds; minute values feed the statistics.
- **Serial**: data is organised in service groups with individual refresh periods – measurements below one second, status every 10 s, counters and temperatures every 30 s, power settings every 70 s, grid values every 90 s and controller statistics every 2 minutes.

- Commands on the serial line are repeated automatically several times to guarantee delivery on noisy lines. If no valid reply is received for 10 s, live values are cleared and the turbine is shown as offline.
- Status, sub-status, warning and sub-warning codes are decoded into plain text.

Available functions

Function	Details
Start / Stop / Reset	Supported on all three communication types.
Active power limit	0–100 % of rated power, 1 % resolution. The resulting limit in kW is calculated from the Turbine Power setting.
Temperatures	Stator, rotor, ambient, nacelle, spinner, front and rear bearing, blades A/B/C, pitch motors A/B/C, pitch batteries, nacelle and control cabinet, tower.
Electrical	U1–U3, I1–I3, P, Q, S, power factor, phase angle, energy delivered; frequency on the serial interfaces.
Master control	Serial types only – see 5.7.

5.2 Mita-Teknik WP3000 (RePower and others)

Controller and typical turbines

The WP3000 is a turbine controller by Mita-Teknik that was installed by many manufacturers in the 1990s and 2000s. WindCtrl supports the WP3000 variants delivered by, among others, **Micon, Nordex, REpower, Fuhrländer, DeWind, Südwind, Tacke, HSW, Bonus, Jacobs, WinCon, WTN, Gaia, Mita, Nordic Windpower, Suzlon and Siva**. The variant is identified automatically when communication starts – it does not need to be selected manually.

Connection

1. Connect the WindCtrl **RS-232** port to the remote / PC port of the WP3000 controller with a shielded serial cable.
2. In **Settings → Communication Settings** set **Url / Ip / Interface** to `/dev/rs232` and select **RePower Serial**.
3. Enter the controller **Service Password** if power limitation is required (see below).
4. Set **Controller Model** to **WP3000 – RePower**, save and reboot.

Operating principle

After start-up WindCtrl identifies the controller variant, authorises itself and then cycles through the data groups: status, temperatures, grid, counters, alarm log, event log and statistics. Because the WP3000 provides its own logbooks, the WindCtrl alarm and event pages also contain the entries recorded by the turbine controller itself.

Available functions

Function	Details
Start / Stop / Reset	Supported.
Active power limit	Supported when the Service Password is configured. WindCtrl converts the requested percentage into the corresponding controller parameter and applies it automatically. Not available while the service menu is being used manually.
Remote service menu	Full remote replica of the WP3000 operator panel, see 7.13. Includes navigation keys, numeric keypad, START / STOP / RESET and yaw commands.
Temperatures	Up to 30 points: ambient, nacelle, gear, gear oil and oil pump, gear bearings, generator windings and bearings, main bearings, cooling water before/after cooler, water forward/return, yaw ring, pitch motors, controller and cabinet temperatures.
Electrical	U1–U3, I1–I3, frequency, P, Q, S, power factor, energy produced and consumed.
Other	Brake status, nacelle and wind direction, rotor and generator speed, operating hours.

CAUTION

Starting a command or a power limit while an automatic service-menu sequence is running interrupts that sequence. Wait until the **Service Menu** page shows the idle state before changing the power limit.

5.3 GE Wind Power – Moeller PLC (Suconet K)

Controller and typical turbines

Early GE Wind Energy turbines (including the 1.5 MW platform inherited from Tacke / Enron Wind) are controlled by a Moeller PLC networked over the Suconet K field bus. WindCtrl connects to this bus as an additional node.

Connection

1. Connect WindCtrl **RS-485-1** to the Suconet K bus of the turbine controller. Respect the bus polarity and termination of the existing installation.
2. If the original remote-monitoring master must remain on the bus, wire the Master Control relay to switch the master role between the original equipment and WindCtrl.
3. In **Settings** → **Communication Settings** set **Url / Ip / Interface** to `/dev/rs485-1` and select **GE Suconet K**.
4. Set **Controller Model** to **GE Wind Power**, save and reboot.

Operating principle

With Master Control **off**, WindCtrl works in passive mode and acquires data without disturbing the existing bus master. When a command is issued, WindCtrl takes the master role temporarily, sends the command, and releases the bus again about 10 seconds later. With Master Control **on**, WindCtrl is permanently the active master.

Available functions

Function	Details
Start / Stop	Supported.
Reset	Supported. For this controller the turbine must be stopped first – a reset on a running turbine is rejected with the message “For this model you need to stop first”.
Active power limit	Not supported by the controller interface.
Data	Status list, wind speed, rotor and generator speed, pitch angle, U1–U3, I1–I3, P, Q, S, power factor, energy delivered and consumed, operating hours.

5.4 GE Wind Power – Bachmann M1 (GE TCP)

Controller and typical turbines

Later GE turbines of the 1.5 MW series use a Bachmann M1 automation system with an Ethernet CPU module. WindCtrl connects over the turbine Ethernet network in the same way as the manufacturer's visualisation software.

Connection

1. Connect WindCtrl **ETH** to the turbine controller network.
2. Assign WindCtrl a free address in the controller subnet.
3. In **Settings → Communication Settings** enter the IP address of the Bachmann CPU in **Url / Ip / Interface** and select **GE TCP**.
4. Set **Controller Model** to **GE Wind Power**, save and reboot.

Available functions

Function	Details
Monitoring	Status and error state, wind speed and direction, nacelle position, rotor and generator speed, pitch angle, U1–U3, I1–I3, P, Q, power factor.
Temperatures	Generator windings 1/2, generator bearings A/B, gearbox, gearbox bearing, shaft bearing, ambient, nacelle.
Control	Monitoring-only in the current release. Start / stop / power limit requests return an error.

NOTE

The IP address entered for GE TCP must be a valid IPv4 address. If it is not, the driver does not start and a critical entry is written to the system log.

5.5 Vestas

Controller and typical turbines

Older Vestas turbines provide a serial service / remote-monitoring port on the turbine controller. WindCtrl reads the operating data through this port.

Connection

1. Connect the WindCtrl serial port (/dev/rs232 or an RS-485 port, according to the turbine port) to the turbine remote port.

2. In **Settings → Communication Settings** enter the interface name and select **Vestas**.
3. Set **Controller Model** to **Vestas**, save and reboot.

Available functions

Function	Details
Monitoring	Status, wind speed, ambient temperature, rotor and generator speed, pitch angle, U1–U3, current, active power, frequency, generator temperature.
Control	Not supported – commands return “Not Supported”.

5.6 Nordex – Phoenix Contact PLC

Controller and typical turbines

Some Nordex turbines are equipped with a Phoenix Contact PLC with an Ethernet interface. WindCtrl reads the operating data from this PLC over the turbine network.

Connection

1. Connect WindCtrl **ETH** to the network of the Phoenix Contact PLC.
2. In **Settings → Communication Settings** enter the PLC IP address in **Url / Ip / Interface**, the service port in **Port**, and select **Phoenix TCP**.
3. Set **Controller Model** to **Nordex**, save and reboot.

Available functions

Function	Details
Monitoring	Status, wind speed and direction, nacelle position, ambient temperature, rotor and generator speed, pitch angle, U1–U3, I1–I3, frequency, P, Q, S, power factor, phase angle.
Temperatures	Generator 1/2, gear oil, generator cooling water, nacelle, ambient.
Control	Monitoring-only in the current release.

5.7 Master Control

On serial and bus-type interfaces only one device can be the active master at a time. When the turbine still has its original remote-monitoring equipment connected, WindCtrl uses its relay output to switch the communication line or the master role between that equipment and itself.

Master Control	Behaviour
Off (default)	Original equipment stays in control of the line. WindCtrl monitors passively. When an operator or the dispatch centre issues a command, WindCtrl switches the relay, executes the command and switches back after approximately 10 seconds.
On	WindCtrl is permanently the active master. Use when the original remote system has been removed or is no longer used.

Master Control is switched with the **Master Control** toggle on the **Dashboard**. The state is stored and restored after a reboot.

6. Installation and commissioning

6.1 Pre-installation checklist

Item	Check
Turbine controller	Manufacturer, controller type and generation identified; interface port located (Ethernet, RS-232, RS-485, remote-monitoring line).
Permits	Written approval from the turbine owner and, where applicable, the service contractor.
Power	Suitable DC supply available in the cabinet with a dedicated fuse / circuit breaker.
Space	DIN rail space for WindCtrl and accessories; adequate ventilation.
Network	Site LAN connection or LTE coverage confirmed; IP addressing plan agreed.
Grid functions	If voltage support is required: grid meter location, CT/VT ratios and the turbine set-point input (4–20 mA or 0–10 V) identified.
Accessories	Serial Extension module (Enercon serial), grid meter, analog output module, antenna, SIM as required.
Documentation	Commissioning sheet with device ID, credentials and network parameters supplied by Smart Tech Innovation.

6.2 Mechanical installation

1. Switch off and lock out the cabinet supply.
2. Mount WindCtrl and the accessory modules on the DIN rail. Keep at least 20 mm free space above and below the unit for ventilation.
3. Route the LTE antenna cable (if used) to a position outside the steel tower or nacelle where reception is adequate. Do not leave the antenna inside a closed metal cabinet.

6.3 Electrical connection

- **Power:** connect the DC supply to the power terminals, observing polarity. Use a separate protective device.
- **Ethernet:** use shielded CAT5e or better. Ground the shield at one end only if there is a risk of ground loops.
- **RS-232:** maximum cable length 15 m. Connect TX, RX and GND only.
- **RS-485:** shielded twisted pair, A/B polarity as marked; terminate both ends of the bus with 120 Ω . Do not terminate in the middle of an existing turbine bus.
- **Relay (Master Control):** wire the changeover contact so that the de-energised state leaves the original remote equipment connected.
- **Analog output module:** connect the output to the reactive power / power factor set-point input of the turbine or converter; observe the signal type (current or voltage) and the input polarity.
- **Grid meter:** connect according to the meter manual (voltage inputs, CTs) and link its communication port to /dev/rs485-2 or to the LAN.

CAUTION

Incorrect RS-485 termination or reversed polarity is the most common cause of intermittent communication. If communication is unstable, check termination and shielding first.

6.4 Network and remote access

WindCtrl can be reached through the site LAN, through a VPN tunnel managed by Smart Tech Innovation, or through the 4G LTE modem. All three may be active at the same time; the controller handles the routing so that requests arriving over the mobile network are answered over the mobile network.

Connection	Use
Site LAN	Local access to the web interface; connection to Modbus TCP / Ethernet turbine controllers and grid meter.
VPN	Secure remote maintenance and fleet management. Each unit receives a dedicated VPN address, visible in Server Central.
4G LTE	Internet uplink for sites without LAN; link to the dispatch centre over the mobile operator network. The mobile connection is activated automatically when a SIM is present.

NOTE

Network addresses, VPN keys and server endpoints are site-specific and are provided in the commissioning sheet. They are not part of this manual.

6.5 Commissioning procedure

1. Insert the SIM card (if used) and switch on the supply. The controller boots in approximately one minute.
2. Connect a laptop to the same LAN and open the web interface (see 7.1). Log in with the credentials from the commissioning sheet and change the password.
3. Open **Settings** and complete the **General** section: device name, turbine model, year, rated power (kW) and **Controller Model**.
4. Complete **Location & Owner** (coordinates, site address, owner and contact person).
5. Configure **Communication Settings** according to the controller chapter in Chapter 5.
6. If installed, configure the **Grid Meter** and **External Settings** (analog output module).
7. Configure **Dispatch Center** and **Server Center** with the values supplied by Smart Tech Innovation or the grid operator.
8. Click **Save**, then **Reboot**. After the restart check that the **Dashboard** shows live values and a decoded status description.
9. Test each control function that will be used (stop, start, reset, power limit) together with the turbine service technician and check the result in the **Event Log**.
10. Record the final settings in the commissioning report.

6.6 Verifying communication

Indication	Meaning
Status shows a code and description	Communication with the turbine controller is established.
Status shows -1 / Offline, values are zero	No valid reply from the turbine for more than 10 seconds. Check cabling, interface name and communication type.
Event "Wind Turbine Controller not selected"	Controller Model is not set or the communication type does not match the controller model.
"Com Interface is not valid Ip"	An Ethernet driver was selected but the interface field does not contain a valid IPv4 address.

7. User manual – web interface

7.1 Accessing the controller

The WindCtrl web interface is available from any modern browser (Chrome, Edge, Firefox, Safari) on the controller's IP address. By default the interface is served on port 8080; on units with HTTPS enabled use the address given in the commissioning sheet.

1. Enter the controller address in the browser, for example `http://<controller-ip>:8080`.
2. Log in with your user name and password. Sessions are protected with signed access tokens and expire automatically.
3. Use **Logout** when you have finished, especially on shared computers.

7.2 Navigation

The left-hand menu is organised in the following groups. The menu can be collapsed on small screens; the interface language and the colour theme can be changed from the top bar.

Menu group	Pages
Dashboard	Dashboard, Overview, Temperature, Generator, Grid, Counters, Power Curve
Log Books	Alarm Log, Event Log
Statistics	Live, Stats Day, Stats Week, Stats Month, Stats Year
Service & Info	Service Menu (WP3000), Extension Menu
Settings & Licence	Settings, Licence Status

7.3 Dashboard

The Dashboard is the main operating screen. It contains:

- **Turbine Monitoring** – turbine model, generic state (Active / Inactive / Error), manufacturer status code and plain-text **Description**, rotor speed, wind speed and active power.
- **Command buttons** – **Start**, **Stop**, **Reset** (see 7.11).
- **Master Control** – toggle for the Master Control relay (see 5.7).
- **Power Limit** – input field in percent and **Set Limit** button.
- **Power Generation** gauge with High / Mid / Low ranges and a **Power Monitor** chart of the last hour showing active power and the active limit.

7.4 Overview

Extended version of the dashboard for engineering use: rotor (R) and generator (G) speed, wind direction compared with nacelle direction, a combined power & wind chart, ambient and gear-oil temperature gauges and **Power Available** – the power the turbine could produce at the current wind speed according to its learned power curve. Comparing Power Available with actual power shows losses due to curtailment or degraded performance.

7.5 Temperature

All temperature measuring points reported by the turbine controller, grouped by component. The number of points depends on the controller (see Chapter 5). Use this page to detect overheating trends of bearings, gearbox and generator before they lead to a stop.

7.6 Generator

Electrical values measured by the turbine: phase voltages and currents, line-to-line voltage, total current, frequency, active / reactive / apparent power and power factor, with live charts for power and for voltage / current.

7.7 Grid

Values from the grid meter at the point of connection (only when a grid meter is configured): phase voltages L1–L3, currents, line-to-line voltage in kV, total current, frequency, active / reactive / apparent power and power factor. These values are also used by the voltage support function (Chapter 8).

7.8 Counters

Cumulative energy counters (energy delivered and consumed) and operating hours as reported by the turbine controller.

7.9 Power Curve

WindCtrl learns the real power curve of the turbine from operating data. Wind speed and active power are filtered with a median filter and recorded only when the turbine is running and **not** curtailed (power limit $\geq 95\%$ or no limit). The curve is stored permanently and updated at most once per minute. The page shows the curve as a chart and as a table (wind speed in m/s versus power in kW).

TIP

A newly installed controller needs several weeks of operation over a wide range of wind speeds before the power curve is complete. The curve is not reset by firmware updates.

7.10 Log books

Alarm Log

Lists alarms with **Type**, **Channel**, **Identifier**, **Description**, **Timestamp**, **Device**, **Severity** and **Ack** (acknowledged). Severity levels are INFO, WARNING, ERROR, MAINTENANCE and CRITICAL. Alarms can be acknowledged individually or all at once; acknowledgement is recorded.

Event Log

Chronological record of all events: status changes reported by the turbine, operator commands, power limit changes, communication events and system messages. Every command entry contains the user and the channel (web interface, dispatch centre, Server Central) that issued it, for example: "Power Limit: 60 applied by operator through Web". Entries prefixed with **(U)** were initiated by a user.

Logbook entries are kept for 365 days and then deleted automatically.

7.11 Operating the turbine

Start, Stop and Reset

1. Confirm that remote operation is permitted and nobody is working on the turbine.
2. Click **Stop**, **Start** or **Reset** on the Dashboard.
3. WindCtrl confirms that the command has been accepted, or displays the reason for rejection (for example “No communication detected” or “Not Supported”).
4. Watch the status **Description**; the turbine executes the command according to its own sequence, which can take from a few seconds to several minutes.

Power limit

Enter a value between 0 and 100 % in **Power Limit** and click **Set Limit**. 100 % removes the limitation. A limit below 100 % is logged as a WARNING event so that curtailment periods remain traceable. The source of the active limit is tracked and displayed:

Source	Meaning
Manual	Set by a user in the web interface or in Server Central.
Dispatch	Set by the grid operator / dispatch centre.
Auto	Set automatically by WindCtrl functions.
Inactive	The controller does not support power limitation.

7.12 Statistics

Page	Content
Live	Real-time charts of the main operating values.
Stats Day	Minute-resolution charts for a selected day: Power Monitor (active, reactive, apparent power and limit), Wind & RPM Monitor, Ambient Temperature, generator and grid electrical values.
Stats Week	Daily energy and averages for the selected week.
Stats Month	Daily energy production, average wind speed, rotor speed and ambient temperature for the selected month.
Stats Year	Monthly energy production and averages for the selected year; multi-year comparison.

Statistics are recorded locally every minute regardless of internet connectivity, and are synchronised to Server Central when it is configured.

7.13 Service Menu (WP3000)

For WP3000 controllers the **Service Menu** page reproduces the operator panel of the turbine controller in the browser, using a live connection. It shows the controller display (main and side rows), the cursor position, the access level and whether the menu is in passive or active use.

Key group	Keys
Operation	START, STOP, RESET, CTRL
Navigation	HOME, END, arrow keys (up, down, left, right), ENTER, ESC, INS, DEL
Numeric	0–9 and decimal point
Yaw	Yaw CCW, Yaw CW, Yaw Stop, Yaw Auto

WARNING

The service menu gives the same access as the local operator panel, including parameter changes and manual yaw. Use it only if you are trained on the WP3000 controller and authorised by the turbine owner.

7.14 Settings

The **Settings** page groups all configuration parameters. Changes take effect after **Save** followed by **Reboot**. **Cancel** discards unsaved changes.

Table 4. Settings reference

Section	Field	Description
General	Device Id	Unique controller identifier (derived from the network interface MAC).
	Mac Interface	Network interface used to derive the Device Id (normally eth0).
	Company Name / Device Name	Names shown in the interface and on Server Central.
	Turbine Model / Year	Free text, e.g. “E-40 / 1998”.
	Turbine Power (kW)	Rated power. Used to convert power limits between % and kW.
	Controller Model	Unknown, Enercon, WP3000 – RePower, GE Wind Power, Vestas, Nordex.
Location & Owner	Latitude / Longitude	Site coordinates (decimal degrees).
	Site Address, Owner Name, Owner Person, Owner Email, Owner Phone	Owner and contact data shown on Server Central.
Dispatch Center	Server URL / IP, Port, User, Password, Token	Connection to the dispatch / SCADA centre. Supplied by the grid operator or Smart Tech Innovation.
Server Center	User, Password, Park Id #	Credentials and park assignment for Server Central.
Grid Meter	Url / Ip / Interface, Port	Interface of the grid meter: serial device (e.g. /dev/rs485-2) or IP address. Leave empty if no meter is installed.
Modbus Server	Port, Unit ID	Parameters of the local Modbus server interface for third-party SCADA systems.
Communication Settings	Url / Ip / Interface, Port	Turbine interface: device name or IP address and port (Ethernet types).
	Communication Type	See Table 2.

Section	Field	Description
	Service Password	Controller service password; required for WP3000 power limitation.
External Settings	Device Type	Analog output module: Waveshare AO 4–20 mA or Waveshare AO 0–10 V.
	Interface, Port, Unit Id	Serial interface, baud rate and Modbus unit ID of the module.

CAUTION

Changing **Controller Model** or **Communication Type** on a running turbine interrupts monitoring until the controller has been rebooted with the new settings.

7.15 Licence Status

Shows whether the controller licence is valid, expired or not registered. An expired licence is reported to Server Central; contact Smart Tech Innovation for renewal.

8. Reactive power and voltage support

Many grid operators require distributed generators to support the local voltage by exchanging reactive power. WindCtrl implements a voltage-dependent power factor characteristic, $Q(U)$, using the grid meter as feedback and the analog output module as actuator.

8.1 Principle

1. The power factor set-point and feedback are taken from the park level (see 8.2) or, for the local characteristic, from the grid meter at the point of connection.
2. Every 10 seconds the park manager compares the measured line-to-line voltage with the nominal value (10 kV for medium-voltage connections in the 9–11 kV range) and calculates the local power factor set-point from the characteristic in Figure 3.
3. Every 2 seconds a closed-loop controller compares the measured power factor with the active set-point and adjusts the analog output (4–20 mA or 0–10 V) that drives the reactive power set-point input of the turbine.
4. The output is limited so that the turbine is only driven in the required direction (capacitive at low voltage, inductive at high voltage). The power factor set-point never falls below 0.94.

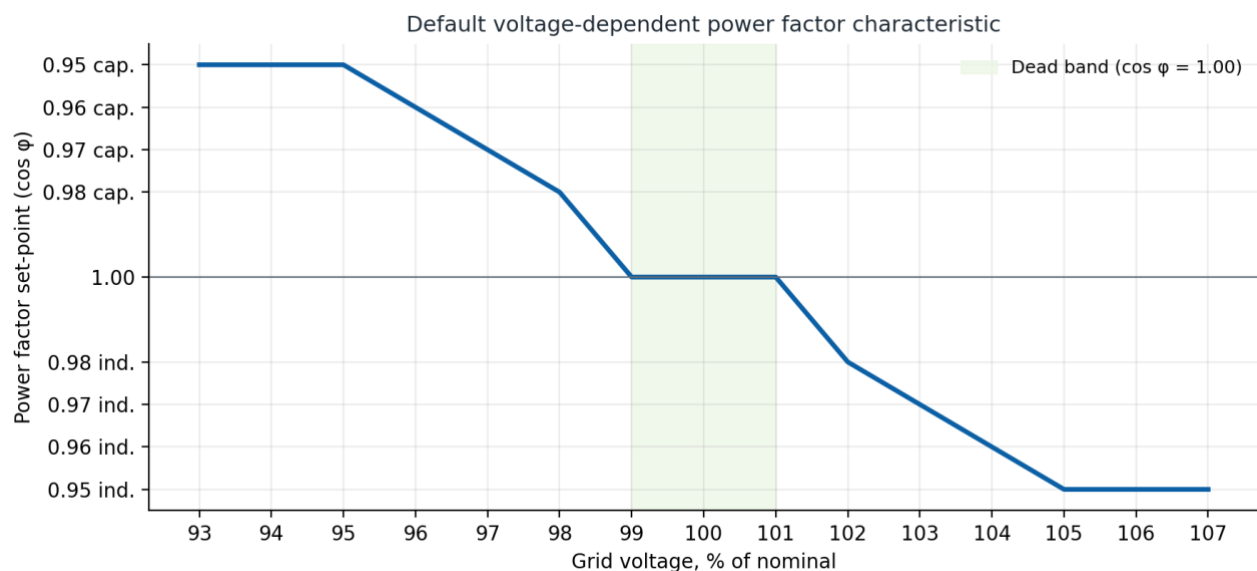


Figure 3. Default $Q(U)$ characteristic – power factor set-point versus grid voltage

Grid voltage	Power factor set-point	Effect
$\leq 95 \%$	0.95 capacitive	Maximum reactive power injection to raise voltage
95 – 98 %	0.95 $\rightarrow$ 0.98 capacitive	Linear transition
99 – 101 %	1.00	Dead band – no reactive power
102 – 105 %	0.98 $\rightarrow$ 0.95 inductive	Linear transition
$\geq 105 \%$	0.95 inductive	Maximum reactive power absorption to lower voltage

8.2 Set-point sources and fail-safe behaviour

- **Park mode** – when the park controller is connected through Server Central (heartbeat received within the last 30 seconds), WindCtrl uses the park-level power factor set-point and feedback. This coordinates all turbines of the park at the common point of connection.

- **Local characteristic** – the local set-point is calculated continuously from the grid meter voltage using the characteristic above and is shown for diagnostics.
- **Fail-safe** – if the park link is lost for more than 30 seconds, or the measured power factor is below 0.90, the analog output returns to its neutral value (14.5 mA for the 4–20 mA module, 5 V for the 0–10 V module), which corresponds to operation at $\cos \phi = 1$.

NOTE

In the current firmware the closed-loop output is driven only while the park link is active. Contact Smart Tech Innovation if the grid operator requires autonomous local Q(U) operation without a park link.

8.3 Configuration

1. Install and configure the grid meter (**Settings → Grid Meter**). Check that the **Grid** page shows correct voltages and power factor.
2. Install the analog output module and select its type in **Settings → External Settings**.
3. Verify with the turbine service team that the set-point input is configured for external reactive power control and that the signal range matches.
4. Save and reboot. Observe the **Grid** page and the turbine reactive power over several voltage conditions.

NOTE

The characteristic shown here is the factory default. Site-specific characteristics required by the grid operator can be configured by Smart Tech Innovation.

9. Remote integration and security

9.1 Dispatch / SCADA link

WindCtrl maintains a permanent outgoing connection to the dispatch centre configured in **Settings → Dispatch Center**. Through this link the dispatch centre can:

- query the current turbine, generator, grid, rotor, environment, device and information data groups;
- issue Start, Stop and Reset commands;
- set an active power limit in percent;
- supervise the connection through periodic heartbeats.

Every request receives a response with a status (OK / Error) and, in case of error, a text message. Commands from the dispatch centre are written to the event log with the channel “Dispatch”. The protocol specification is available to grid operators and integrators on request.

9.2 Server Central

Server Central is Smart Tech Innovation's fleet monitoring platform, available as a cloud service or as a private server. Each WindCtrl reports live data, alarms, events and statistics, and Server Central can read and update the controller settings remotely. A park view aggregates all turbines of a site: total active and reactive power, available power, average wind speed and the number of turbines that are active, inactive, in error, in maintenance or offline.

9.3 Security recommendations

- Change all default passwords at commissioning; use different passwords for every site.
- Do not expose the web interface directly to the internet. Use the VPN for remote access.
- Restrict the turbine controller network to WindCtrl and authorised service equipment.
- Keep automatic updates enabled so that security fixes are applied promptly.
- Review the Event Log regularly for unexpected commands or login activity.

10. Maintenance

10.1 Firmware updates

When the controller is online it checks for a new firmware release every 5 minutes (first check 2 minutes after boot). A new release is downloaded and started automatically; the restart takes less than one minute and does not affect configuration, logbooks, statistics or the learned power curve. Communication with the turbine resumes automatically after the restart.

10.2 Data storage

Data	Retention
Configuration	Permanent, until changed
Alarm and event logbooks	365 days
Minute statistics	Rolling window; aggregated day / month / year values kept long-term
Power curve	Permanent, updated continuously
System log	Rotated automatically

10.3 Periodic checks

- Check that the Dashboard status corresponds to the turbine's local display (annually or after turbine controller service).
- Inspect cable connections, shielding and the LTE antenna during scheduled turbine maintenance.
- Verify the grid meter readings against the utility meter once per year.
- Review unacknowledged alarms and acknowledge resolved ones.

11. Troubleshooting

Symptom	Possible cause	Action
Dashboard values are zero, status -1	No communication with the turbine controller for more than 10 s	Check cable and connectors, interface name, communication type and, for RS-485, polarity and termination.
"Wind Turbine Controller not selected"	Controller model not set or not matching communication type	Set Controller Model and Communication Type according to Table 2; save and reboot.
"No communication detected" on command	Enercon serial: line not active	Check the Serial Extension module and its USB connection; check the turbine line.
"Check Extension Serial Module"	Serial Extension module not found	Verify the module is connected and the interface is /dev/ttyACM0.
"For this model you need to stop first"	GE Suconet K reset on a running turbine	Stop the turbine, wait for the stopped state, then reset.
"Error: Service Password not set"	WP3000 power limit without service password	Enter the Service Password in Communication Settings.
"Error: Service Menu In Operation"	WP3000 service menu is in use	Leave the Service Menu idle, then repeat the power limit.
"Not Supported" / "Command not supported"	Function not available for this controller	See the feature matrix (Table 3).
Grid page empty	Grid meter not configured or not reachable	Check Grid Meter settings, wiring, unit ID and baud rate.
Power curve incomplete	Insufficient operating time or turbine curtailed	Allow more operating time without power limitation.
Web interface not reachable	Wrong address, network or VPN issue	Check the IP address, LAN cable and VPN status; contact support for remote diagnostics.
Status description "Unknown"	Status code not in the description table	Report the status code to Smart Tech Innovation support.

Appendix A. Generic states and status

Independently of the manufacturer-specific codes, every turbine is mapped to the following generic values, which are used by the dashboard colours, Server Central and the dispatch link.

Generic state	Meaning
Inactive	Turbine not producing (stopped, waiting for wind, standby).
Active	Turbine running / producing.
Error	Turbine stopped due to a fault.
Maintenance	Turbine in service mode (device level).
Offline	No communication with the turbine controller.

Generic status	Meaning
OK	No active warnings or errors.
Warning	Turbine running with an active warning.
Error	Active fault.
Maintenance	Maintenance status reported by the controller.

Appendix B. Glossary

Term	Definition
CM4	Raspberry Pi Compute Module 4 – processor module of the WindCtrl hardware.
Curtailement	Deliberate reduction of the turbine output below the available power.
Dispatch centre	Control room of the grid operator or park operator that sends set-points and commands.
Master Control	WindCtrl function that switches the turbine communication line / master role using a relay.
Modbus RTU / TCP	Open industrial communication standard over serial lines or Ethernet.
Power Available	Power the turbine could produce at the current wind speed according to its learned power curve.
Q(U)	Voltage-dependent reactive power control.
Server Central	Smart Tech Innovation fleet monitoring platform.
Serial Extension	WindCtrl USB line adapter for Enercon serial remote-monitoring lines.
VPN	Virtual private network used for secure remote access.

Appendix C. Support

Manufacturer	Smart Tech Innovation S.R.L., Republic of Moldova
Product page	smartinnovation.md/en/windctrl
E-mail	smartinnovation.md@gmail.com
When contacting support	Provide the Device Id, controller model, communication type, firmware version and a description of the issue with the time it occurred.