

ANNEXE O

FICHES TECHNIQUES DU SHADOW MODULE

Technical Description

ENERCON wind energy converters
Shadow shutdown

Legal notice

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1 Introduction

Periodic shadow casting (or shadow flickering) is caused by movement of the rotor blades, which shut out the sunlight and create a flickering effect while the rotor is in motion. The occurrence of this effect depends on the current local weather conditions, alignment of the nacelle with the wind direction, the position of the sun, and the wind energy converter (WEC) operating hours.

The objective of the ENERCON shadow shutdown function is to specifically shut down the wind energy converter, taking into account the current weather conditions, and thus to reliably prevent or reduce shadow flickering in relevant locations where it could be a nuisance (e.g. living rooms, bedrooms, schools, patios, etc.).

2 Operating principle

The ENERCON shadow shutdown is a function that is integrated into the control system of ENERCON WECs. It is specifically activated in any WEC where shadow shutdown becomes necessary. Each ENERCON wind energy converter is controlled autonomously. Shutting down multiple WECs at the same time by means of a system such as wind farm control is unfeasible.

Programming and parameter configuration for the ENERCON shadow shutdown function are performed on the control cabinet display of the wind energy converter.

2.1 Determining potential shadow shutdown times

The ENERCON shadow shutdown function is based on a calendric system. The times of the maximum astronomical shadow casting potential at affected immission sites are computed considering site-specific parameters such as hub height, rotor diameter, WEC coordinates, location of the immission site, and topography.

Results include the shadow casting periods at relevant immission sites, indicating daily start and end times of periodic shadow casting. The shutdown times determined are programmed into the ENERCON WEC control system as a table. Fine-tuning of these shutdown times is feasible at any time for each immission site and time period.

2.2 Measuring illuminance

Actual shadow flickering caused by movement of the WEC rotor blades depends on insolation. According to the German Federal States' Immission Control Committee (Länderausschuss für Immissionsschutz), shadow flickering is likely when the sunlight is greater than 120 W/m^2 at the level vertical to the incidence direction.

The level of illuminance on a horizontal measuring surface is influenced by the incidence angle of the sun (position of the sun) and the photometric equivalent. The latter is determined by refraction and atmospheric opacity; it also depends on the position of the sun. The illuminance depending on the sun's position can therefore only be approximated. In addition, the current position of the sun is unknown to the WEC control system.

Therefore, a procedure has been developed for the ENERCON shadow shutdown function to precisely assess the shadow casting potential at any time. To measure illuminance, three sensors are fitted to the bottom section of the ENERCON wind energy converter tower; these are spaced at 120° angles. This arrangement ensures that at least one sensor is always on the sunny side and one sensor is in the shade of the tower. Based on the measured values from the three sensors, the control system determines the highest and the lowest illuminance values, i.e., the light intensity and the shadow intensity. Instead of an inherently inaccurate measurement of illuminance, the ratio of shadow to light intensity – also referred to as shutdown intensity – is therefore used to determine whether shadow casting is likely to occur.

With an illuminance of 120 W/m^2 , the measured shutdown intensity is 36 %. This value is virtually independent of the position of the sun. Once the ratio of shadow to light intensity drops below 36 %, illuminance is greater than 120 W/m^2 . Shadow casting occurs. This value has been validated in the setting of a two-year field test of shadow shutdown modules. Shutdown intensity can be modified individually as needed.

2.3 Automatic shutdown

The ENERCON shadow shutdown is activated and the ENERCON wind energy converter stops once the shutdown intensity value falls below the setpoint inside the programmed shutdown time frame.

No average is computed for the measured illuminance. Automatic shutdown will therefore respond even if the value falls below the reference value only briefly. Filtering times can be used to define a delay in the response of the start-stop mechanism. The *Filtering time on* parameter specifies for how long the shadow intensity has to be below shutdown intensity (on average) until shadow shutdown is activated. The *Filtering time off* parameter specifies for how long the shadow intensity has to be above shutdown intensity (on average) until shadow shutdown is deactivated.

If the light conditions change such that shadow flickering is no longer possible, shadow shutdown will remain active initially. Shadow shutdown will not be deactivated until the programmed time period has elapsed or light conditions have not changed for a specified time period (as a rule, more than five minutes) and shadow flickering was not possible during that period. The WEC resumes operation.

3 Tolerances and reliability

The sensor used for measuring illuminance typically has a tolerance of $\pm 10\%$. Following inspection of the sensors, a set of three sensors with a maximum tolerance of $\pm 1\%$ towards one another is selected at the factory within the framework of the quality assurance process. As no absolute measured values but only the ratio of the illuminance values is important for signal interpretation, a very high degree of accuracy is achieved.

In addition, the function of the light sensors is automatically checked for plausibility twice daily during operation. This involves measurement of the voltages at the three light sensors at midnight and at 1:00 p.m. If the measured values are implausible, a message will be sent to ENERCON Service and technicians will check the sensors on site and replace them, if necessary.

Failure of a sensor, e.g. due to a broken cable or short-circuiting, results in the ratio of shadow to light intensity falling below the shutdown intensity value. The ENERCON wind energy converter stops outside the programmed time frame. The WEC control system generates a warning message indicating which of the three sensors has failed.

4 Logging and availability

Activation of the ENERCON shadow shutdown system is recorded as a status message by the remote data transmission system together with its date, time and duration and is then stored for several years.

If required, measured data from the light sensors are logged. The ratio of shadow to light intensity is recorded as an average per minute; the minimum and maximum values at one-minute intervals and the defined shutdown intensity are also recorded.

The ENERCON shadow shutdown function is available for all WECs from ENERCON's current product range.

Shadow Management

Product Description

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Applicable Documents

The documents referred to in the table below are included for information only. Reference to them in this product description does not make them part of the contract.

Title	Document no.
General Information: REguard Scada System	GI-0.0-RG.GE.01-A-*-EN
Specification: Communication connection on the wind farm	V-1.1-SL.KM.20-A-*-EN

* If the products referred to in the table above are to be included within the project, the relevant product descriptions in their current version will be amended to the contract.

List of Abbreviations and Units

Abbreviation/Unit	Description
BImSchG	Bundes-Immissionsschutzgesetz (German Federal Immission Protection Law)
WEC	Wind energy converter

1 Introduction

Wind energy converters (WEC) may cause periodic shadow casting by means of the turning rotor under certain circumstances. In order to limit the temporal extent of the shadow casting on houses in the proximity there are federal restrictions like the German Federal Immission Protection Law (BImSchG)¹ that provide reference values. The deactivation of WEC is provided if the shadow cast on the immission point exceeds these legally provided reference values. The *Shadow Management* realizes the corresponding control for the deactivation of the WEC.

If the responsible authorising agency demands a shadow cast control for a WEC site, it lies in the exclusive responsibility of the customer to provide a shadow cast report at his own expense.² Based on this report the on-site survey takes place, which is necessary for the site-specific configuration of the shadow cast module.

The *Shadow Management* is an optional product for REpower *MM*, *3.XM*, *5M* (onshore) and *6M* WEC (onshore).

2 Functional description

The deactivation of the WEC is realized via the shadow cast module. The module receives incoming solar radiation measurements via a light sensor and current time data via an integrated time signal receiver. Based on this information, the module calculates whether shadow is cast on buildings in the proximity and whether this exceeds the provided reference values at the immission point. If that is the case, the corresponding WEC will be deactivated for the duration of the shadow cast.

¹ „Gesetz zum Schutz vor schädlichen Umwelteinwirkungen durch Luftverunreinigungen, Geräusche, Erschütterungen und ähnliche Vorgänge“, as amended and promulgated on September 2, 2002, last amended by article 1 on October 23, 2007.

² To prepare according to the „Hinweisen zur Ermittlung und Beurteilung der optischen Immissionen von Windenergieanlagen des Länderausschusses für Immissionsschutz, Stand 13.03.2002“.

3 Planning information

One module is able to monitor the shadow cast by 12 WEC on up to 100 immission points and deactivate these WEC upon exceeding the reference values. In addition, the preload of up to 38 WEC may be taken into consideration.³ However, these WEC may not be controlled via the shadow cast module.

If a site requires the control of more than 12 WEC, multiple shadow cast modules may be operated parallel on the wind farm.

4 Technical data

4.1 Switching cabinet with module

Voltage supply: 230 V

Max. power consumption: 30 W

Operating temperature: -10 through +50 °C

Protection class: IP 65

4.2 Light sensor

Voltage supply: 24 V DC (the power supply has been installed in the switching cabinet)

Operating temperature: -20 through +50 °C

Protection class: IP 66

³ If the reference value for the shadow cast on an immission location is exceeded only after adding a new WEC close to an existing wind farm which already cast shadow on the immission point, but has not exceeded the reference value in the past, these previously installed WEC must be taken into consideration as preload. The preload has to be included in the shadow cast report that is provided by the customer. Based on this calculation the preload is configured in the shadow cast module.

5 Scope of supply and performance

The scope of supply and performance comprises:

- Switching cabinet with shadow cast module
- Light sensor incl. bracket
- Time signal receiver
- Survey of WEC site(s) that cause shadow cast⁴
- Survey of immission point(s)⁵
- Consideration of the preload due to other WEC (if available, according to shadow cast report) in shadow cast module configuration⁶
- Configuration of the shadow cast module based on survey results
- Assembly and commissioning of the components listed under point 5

Information about the required telecommunication connection is provided in the "Specification for the communication connection on the wind farm" (V-1.1-SL.KM.20-A-*-EN). An adequate communication connection has to be provided by the customer up to the time of commissioning of the WEC, and is required for the use of the *Shadow Management*.

Any required appraisals - irrespective of the reason – by independent institutes for the shadow cast or the review of the installation of the shadow cast module are not included in the scope of supply.

6 General comments

The *Shadow Management* may be procured in connection with a *REpower* WEC only. Please consult your *REpower Systems AG* sales partner whether the *Shadow Management* is available for your specific WEC configuration.

⁴ Relevant WEC are defined in advance by shadow cast report

⁵ Relevant immission points defined in advance by shadow cast report

⁶ Preload by other WEC defined in advance by shadow cast report