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Wind energy generation systems - Part 40: Electromagnetic compatibility (EMC) - Requirements and test methods

Systèmes de génération d'énergie éolienne - Partie 40: Compatibilité électromagnétique (CEM) - Exigences et méthodes d'essai

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CONTENTS

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Wind energy generation systems - Part 40: Electromagnetic compatibility (EMC) - Requirements and test methods

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The text of this International Standard is based on the following documents:

Draft	Report on voting
88/1131/FDIS	88/1144/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts of the IEC 61400 series, under the general title: *Wind energy generation systems*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

– reconfirmed,
– withdrawn, or
– revised.

1 Scope

This part of IEC 61400 provides the EMC requirements and test methods that apply to the individual wind turbine and all the sub systems which are part of the wind turbine.

The current document applies to measurements on individual wind turbines and not multiple wind turbines.

This document defines the requirements and test methods for the verification of the wind turbine performance against radiated emissions and the immunity of their components against conducted and radiated phenomena.

This document is applicable to onshore and offshore wind turbines.

Safety considerations are not covered by this standard.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC TR 61000-2-5, *Electromagnetic compatibility (EMC) - Part 2-5: Environment - Description and classification of electromagnetic environments*

IEC 61000-4-2, *Electromagnetic compatibility (EMC) - Part 4-2: Testing and measurement techniques - Electrostatic discharge immunity test*

IEC 61000-4-3, *Electromagnetic compatibility (EMC) - Part 4-3: Testing and measurement techniques - Radiated, radio-frequency, electromagnetic field immunity test*

IEC 61000-4-4, *Electromagnetic compatibility (EMC) - Part 4-4: Testing and measurement techniques - Electrical fast transient/burst immunity test*

IEC 61000-4-5, *Electromagnetic compatibility (EMC) - Part 4-5: Testing and measurement techniques - Surge immunity test*

IEC 61000-4-6, *Electromagnetic compatibility (EMC) - Part 4-6: Testing and measurement techniques - Immunity to conducted disturbances, induced by radio-frequency fields*

IEC 61000-4-8, *Electromagnetic compatibility (EMC) - Part 4-8: Testing and measurement techniques - Power frequency magnetic field immunity test*

IEC 61000-4-11, *Electromagnetic compatibility (EMC) - Part 4-11: Testing and measurement techniques - Voltage dips, short interruptions and voltage variations immunity tests for equipment with input current up to 16 A per phase*

IEC 61000-4-34, *Electromagnetic compatibility (EMC) - Part 4-34: Testing and measurement techniques - Voltage dips, short interruptions and voltage variations immunity tests for equipment with input current more than 16 A per phase*

IEC 61000-6-2, *Electromagnetic compatibility (EMC) - Part 6-2: Generic standards - Immunity standard for industrial environments*

IEC 61400-1, *Wind energy generation systems - Part 1: Design requirements*

IEC 61400-2, *Wind turbines - Part 2: Small wind turbines*

CISPR 11:2024, *Industrial, scientific and medical equipment - Radio-frequency disturbance characteristics - Limits and methods of measurement*

CISPR 16-1-1:2019, *Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-1: Radio disturbance and immunity measuring apparatus - Measuring apparatus*

CISPR 16-1-4, *Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-4: Radio disturbance and immunity measuring apparatus - Antennas and test sites for radiated disturbance measurements*

CISPR 16-1-6, *Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-6: Radio disturbance and immunity measuring apparatus - EMC antenna calibration*

CISPR 16-2-3:2016, *Specification for radio disturbance and immunity measuring apparatus and methods - Part 2-3: Methods of measurement of disturbances and immunity - Radiated disturbance measurements*
CISPR 16-2-3:2016/AMD1:2019
CISPR 16-2-3:2016/AMD2:2023

CISPR 16-4-2, *Specification for radio disturbance and immunity measuring apparatus and methods - Part 4-2: Uncertainties, statistics and limit modelling - Measurement instrumentation uncertainty*

3 Terms, definitions, abbreviated terms and units

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61400-1, IEC 61400-2 and CISPR 11 apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

– IEC Electropedia: available at https://www.electropedia.org/
– ISO Online browsing platform: available at https://www.iso.org/obp

3.2 Abbreviated terms and units

NOTE 1 Generic abbreviations are used in this document.

NOTE 2 Only generic symbols and units are used in this document.

EMI electromagnetic interference
EUT equipment under test
ESD electrostatic discharge
EFT electrical fast transient

4 Operating conditions during testing

Operating conditions specific for this document are included in the relevant clauses.

5 Emission requirements

5.1 General

The wind turbine shall fulfil the emission requirements of this document.

Additional requirements for main converters of wind turbines are shown in Annex B.

Changes on a wind turbine can have an effect on the EMC behaviour of the wind turbine. An overview of the main characteristics that can have influence on EMC behaviour of a wind turbine is described in Annex A.

5.2 Conducted emissions

For radio protection purposes, the radiated magnetic emissions of the whole wind turbine are measured in the range of 150 kHz to 30 MHz (conducted emissions frequency range). Instead of measuring the common mode/differential mode currents, the radiated magnetic emissions generated by these currents are measured as described in 5.3.

Harmonic, interharmonic and higher frequency emission requirements which are relevant to power quality for grid connected wind turbines are handled in IEC 61400-21-1 [1][1] and are out of scope of this document.

5.3 Radiated emissions

5.3.1 General

Due to continuous variation of wind speed and other external influences, the emissions of wind turbines can vary during the measurements. The emissions from the wind turbine shall be distinguished from ambient signals.

An overview of a recommended test sequence is given in Figure 1 and Table 1.

Description of Figure 1:

The measurements shall be executed under the following conditions:

- Reference points and orientations of the antenna are given in 5.3.7.
- The settings of the EMI-receiver are given in 5.3.7.
- The operating modes of the wind turbine are given in 5.3.8.
- To distinguish the emission of the wind turbine from prevailing ambient emissions, all measurements on one reference point of the antenna should be executed in sequence in one (short time) block like shown in Table 1. This is to ensure minimum natural ambient emissions variations influencing the measurements. The assessment for ambient emission detection given in CISPR 16-2-3:2016, Subclause A.4.3 to Clause A.5 shall be used.
- Discontinuous disturbances which occur sporadically shall be disregarded, like described in CISPR 16-2-3:2016, 6.5.1.

[1] Numbers in square brackets refer to the Bibliography.

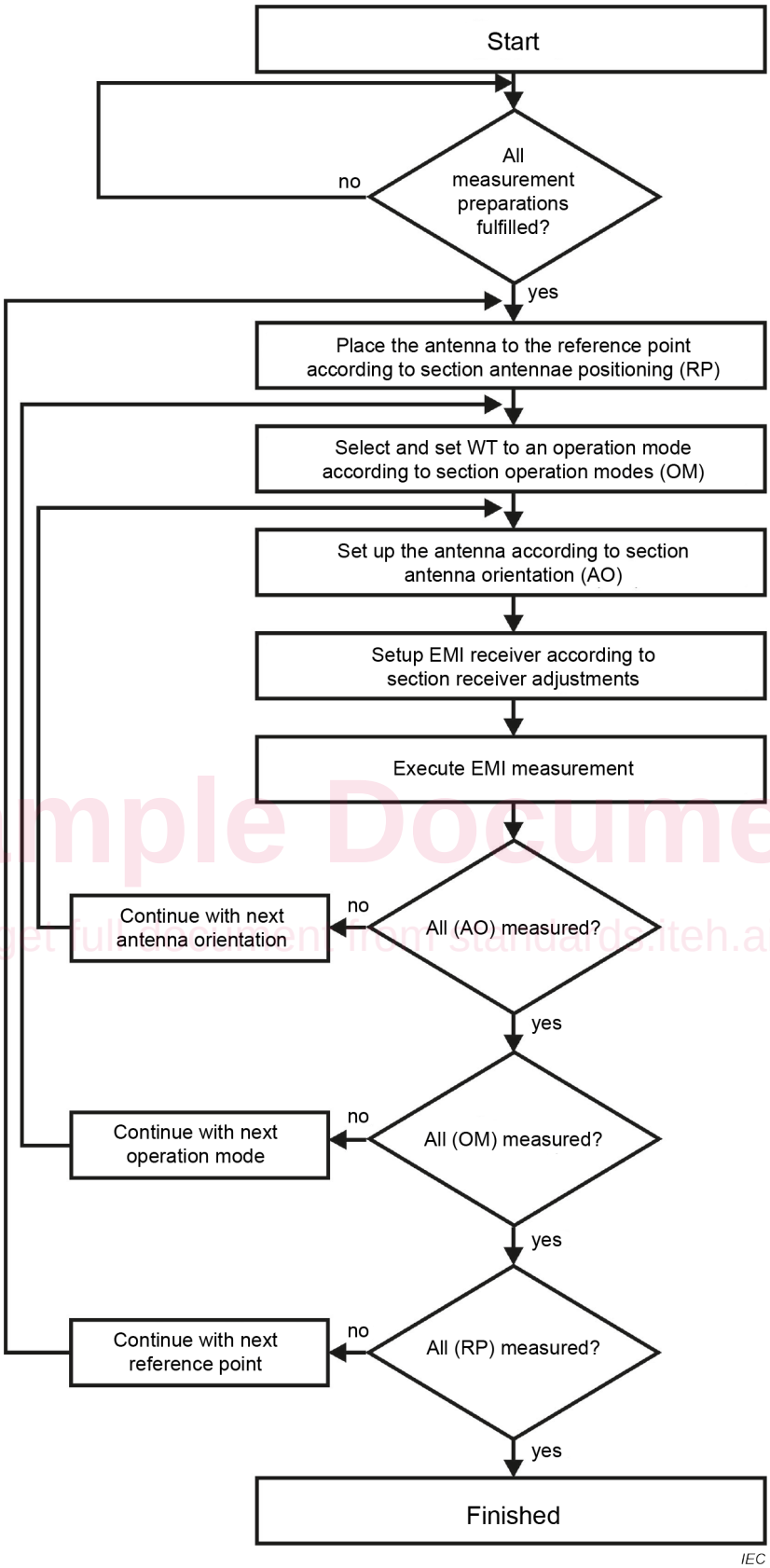

Figure 1 – Recommended flow chart of EMI measurement

NOTE Additional elevation angles can occur.

Table 1 – Summary of measurements for each reference point of the antenna

Id	Operating mode	Type of measurement	Frequency range	Antenna elevation	Antenna polarization
1	Disconnected from the grid	Magnetic field	150 kHz to 30 MHz	-	Radial
2	Disconnected from the grid	Electric field	30 MHz to 1 GHz	Tower base	Vertical
3	Disconnected from the grid	Electric field	30 MHz to 1 GHz	Tower base	Horizontal
4	Disconnected from the grid	Electric field	30 MHz to 1 GHz	Nacelle	Vertical
5	Disconnected from the grid	Electric field	30 MHz to 1 GHz	Nacelle	Horizontal
6	Standby mode	Magnetic field	150 kHz to 30 MHz	-	Radial
7	Standby mode	Electric field	30 MHz to 1 GHz	Tower base	Vertical
8	Standby mode	Electric field	30 MHz to 1 GHz	Tower base	Horizontal
9	Standby mode	Electric field	30 MHz to 1 GHz	Nacelle	Vertical
10	Standby mode	Electric field	30 MHz to 1 GHz	Nacelle	Horizontal
11	Medium load operation	Magnetic field	150 kHz to 30 MHz	-	Radial
12	Medium load operation	Electric field	30 MHz to 1 GHz	Tower base	Vertical
13	Medium load operation	Electric field	30 MHz to 1 GHz	Tower base	Horizontal
14	Medium load operation	Electric field	30 MHz to 1 GHz	Nacelle	Vertical
15	Medium load operation	Electric field	30 MHz-1 GHz	Nacelle	Horizontal
16	Increased load operation	Magnetic field	150 kHz to 30 MHz	-	Radial
17	Increased load operation	Electric field	30 MHz to 1 GHz	Tower base	Vertical
18	Increased load operation	Electric field	30 MHz to 1 GHz	Tower base	Horizontal
19	Increased load operation	Electric field	30 MHz to 1 GHz	Nacelle	Vertical
20	Increased load operation	Electric field	30 MHz to 1 GHz	Nacelle	Horizontal

5.3.2 Measurement system

5.3.2.1 General

Antenna calibration at 10 m distance is acceptable for the testing at all distances according to this document which are ≥10 m.

CISPR 16-1-4 and CISPR 16-1-6 provide precise information for the calibration of antennas.

The EMI receiver shall fulfil the requirements specified in CISPR 16-1-1 and CISPR 16-2-3.

5.3.2.2 Auxiliary measurement equipment

It is not necessary to calibrate the auxiliary measurement equipment, as the values are informative.

NOTE The following are examples of the auxiliary measurement equipment: distance meter, clock, compass, sensors of wind turbine data and sensor of meteorological data.

The sensor of meteorological data shall be placed at the measuring site within the perimeter of 100 m radius from the tower.

5.3.3 Data recording

Operation data of the wind turbine that are helpful to replicate the measurement should be recorded. At least the active power values shall be documented in the test report in 10 minutes RMS values, as well as the yaw angle in 10 minutes average values.

Other required operation data of the wind turbine shall be recorded at least in 10 minutes average values with a time stamp.

At least every 10 minutes, one set of meteorological data shall be recorded (air humidity, air temperature).

The timestamp of the recorded data shall be referenced to a common time reference with the purpose of being able to make a correlation between the different measurements.

Radiated emissions levels which have been measured shall be recorded.

The data shall be used to generate documentation of the results of the measurements.

5.3.4 Requirements for the wind turbine

During the measurement, the power output of the wind turbine should be controlled to get the operating modes according to 5.3.8.

If such function is not available, the measurements shall be done while the required measurement conditions are reached by the available windspeed according to 5.3.8.

5.3.5 Requirements for the measurement site

The surface between the reference points of the antenna and the wind turbine should be as flat and level as possible, accessible and free from obstacles in direction towards the wind turbine.

If a foundation mound is present for the wind turbine, it is defined to be part of the wind turbine.

The measurement site shall be documented in the test report.

5.3.6 Weather conditions

Weather conditions can have a significant impact on the measurement results. In order to minimize their effect on the measured field strength levels, measurements should be carried out in dry weather, free from precipitation, fog, upcoming thunder storms and higher field strength conditions or significant weather changes.

5.3.7 Measurement setup

5.3.7.1 Settings of the EMI-receiver

At least the following EMI receiver settings shall be used:

– quasi-peak detector;
– observation time for each frequency step shall be longer than the slowest full rotation time of the wind turbine rotor which is possible while generating active power;
– 150 kHz to 30 MHz: resolution bandwidth 9 kHz;
– 30 MHz to 1 000 MHz: resolution bandwidth 120 kHz;
– frequency step size for measurements: 50 % of the resolution bandwidth or less.

5.3.7.2 Antenna positioning

– The antenna reference point shall be aligned with respect to the wind turbine hub, in four orthogonal directions, aligned with the four sides of the nacelle seen from the top (see Figure 2).

– If a tower door exists, additional measurements shall be performed in alignment and directed towards the tower door (see Figure 2). If the wind turbine has no door in the tower base, this antenna reference point does not apply.

– The horizontal distance between the outer boundary of the tower at ground level of the wind turbine and the reference point of the measurement antenna shall be 30 m with an accuracy of ± 5 %.

– Additionally, two more reference points shall be defined. Those two reference points shall have a horizontal distance of 65 m and 100 m in any direction with an accuracy of ± 5 %. In case of high emissions detected, as an example coming from buried cables close to a refence point, a new reference point shall be found. A possible procedure is shown in Annex E.

– By referring to CISPR 16-2-3, measurement distance is the horizontal distance from the outer wall of the wind turbine tower to the reference point of the antenna.

– The antenna reference point in relation to the hub shall be noted into the test report. In case the wind turbine yaw angle varies more than ± 15° at one reference point, the reference point shall be re-aligned with the hub/nacelle and the measurements of the last operation mode shall be repeated.

– For detection of underground power cables, the antenna reference point can be shifted by ± 15° or by changing the measurement height. If a power cable was positively detected at an antenna reference point and limits are exceeded because of the magnetic fields emitted by the cables, those results shall be void and replaced by a new antenna reference point, which is at least 30° away from any existing valid antenna reference point. A possible procedure is shown in Annex E.

– If another electrical system is part of the EUT, such as an external transformer, other antenna reference points are required. The orthogonal system of axes as described above is copied and shifted so that the origin of the new axis systems is positioned on the additional electrical system (see Figure 3 for orientation). A new antenna reference point is defined at a horizontal distance of 30 m from the system in the opposite direction to the wind turbine. The other antenna reference points shall be adjusted to points like shown in Figure 3. Two overlapping circles centred at the midpoint of the midpoint of the wind turbine and the electrical system outside of the wind turbine, with at distance between the outer walls of both the wind turbine and the outside electrical system and the antenna reference points of 30 m, shall be used as shown in Figure 3. The measurement points should be placed on the perimeter of the constructed overlapping circles with an accuracy of ± 5 % with respect to the measurement distance.

– In presence of radio systems at measurement site, like described in CISPR 11:2024, Clause 10, the procedure of CISPR 11:2024, Clause 10 shall be followed.

5.3.7.3 Measurement antenna

The antenna should be positioned as described below.

– The magnetic field strength in the frequency range from 150 kHz to 30 MHz shall be measured in the direction of maximum radiation with the wind turbine in the mode of operation generating the highest disturbance field strength. A loop antenna described in CISPR 16-1-4:2019 and CISPR 16-1-4:2019/AMD2:2023, 4.3.2 shall be used as referenced in CISPR 16-2-3:2016, 7.7.2, CISPR 16-2-3:2016/AMD1:2019, 7.7.2 and CISPR 16-2-3:2016/AMD2:2023, 7.7.2. The configuration is shown in Figure 4.

– The electric field strength in the frequency range from 30 MHz to 1 000 MHz shall be measured in the direction of maximum radiation with the wind turbine in the mode of operation generating the highest disturbance field strength using broadband antennas. The configuration is shown in Figure 5. If additional points of maximum radiation are available, an additional elevation angle shall be chosen for these measurements.

– Two elevation angles shall be used for each E-field antenna position. See Figure 5:
  - zero degrees pointing at the base of the tower,
  - pointing towards the nacelle.
– The distance between the lowest point of the E-field-antenna and the ground shall be 0,25 m or more as described in CISPR 16-2-3:2016, 7.3.5. The antenna reference point height shall be 2,0 m ± 0,2 m and all measurements shall be carried out in horizontal and vertical polarization. This shall be followed since a height scan is not practical for a wind turbine.

NOTE For magnetic field measurements, the experience and simulations have shown that the maximum radiated emissions will be measured if the magnetic field antenna is mounted in radial direction to the wind turbine as shown in Figure 4.

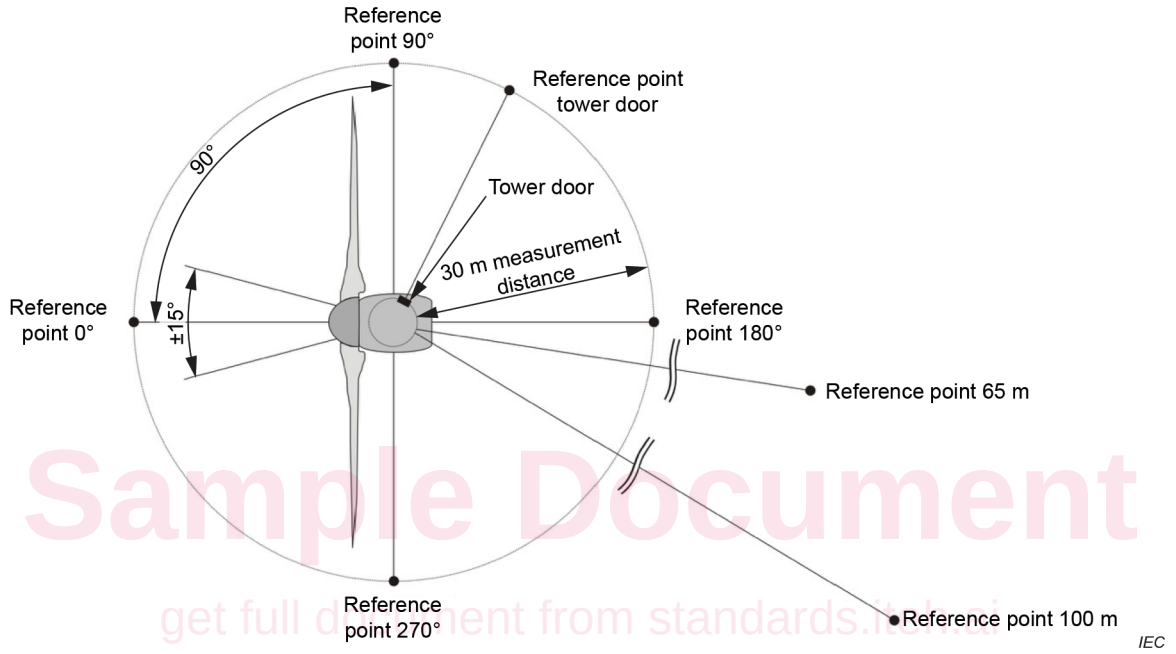

Figure 2 – Example of a test configuration for an EMC measurement on a wind turbine – Reference points relative to the wind turbine hub

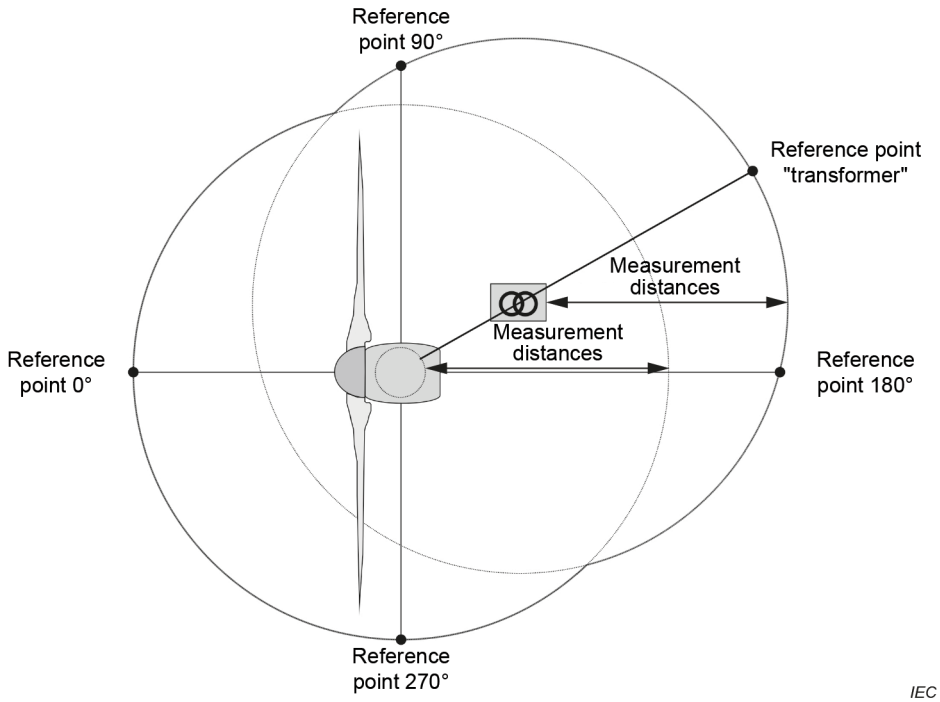

Figure 3 – Example of a test configuration with a transformer

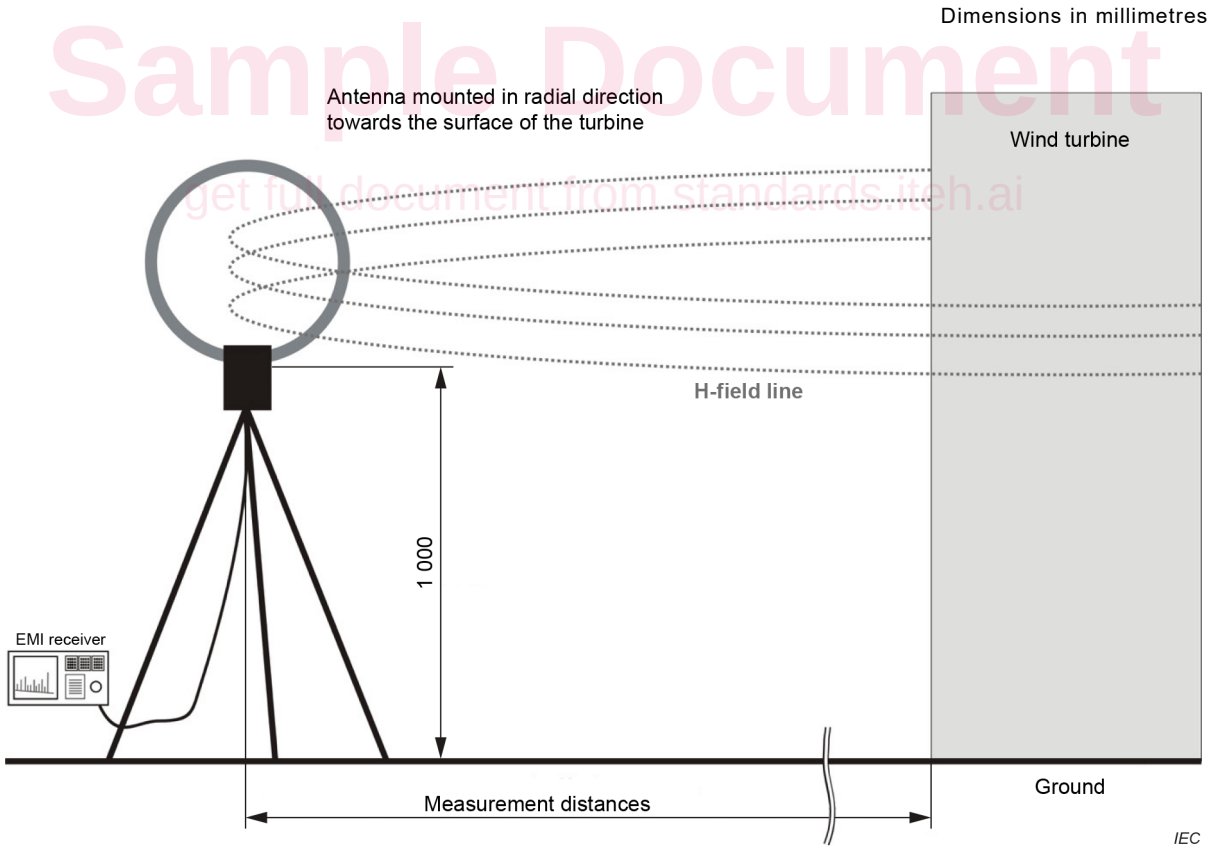

Figure 4 – Example of a test setup of a magnetic field strength measurement