GHANA CIVIL AVIATION GUIDELINES, 2016

MANAGING THE RISK OF WIND TURBINE DEVELOPMENTS (WIND FARM)/WIND MONITORING TOWER INSTALLATIONS TO AVIATION SAFETY

Contents

INTRODUCTION

Owing to their size, wind turbines are assessed as a vertical obstruction as any other tall structure, such as a mast or tall building, would be assessed. Wind farms can be hazardous to aviation as they are tall structures with the potential to come into conflict with low flying aircraft. Temporary and permanent wind monitoring towers can be erected in anticipation of, or in association with, wind farms and can also be hazardous to aviation, particularly during low visibility. In addition to the hazard posed to aircraft in approaching or departing from an airfield, wind turbines can also pose a potential danger to aircraft flying at a low level for any other reason. These structures can also affect the performance of Communications, Navigation and Surveillance equipment operated by the Ghana Civil Aviation Authority (GCAA).

This document provides guidance to Organizations, Local Government decision makers, airport operators and developers of wind farms to jointly address the risk to civil aviation arising from the development, presence and use of wind farms and wind monitoring towers. As aerodromes and proposed aerodromes are protected from tall structures in the vicinity of aerodromes based on standards established by the International Civil Aviation Organization (ICAO), these Guidelines can be used to ensure wind farms hazardous to aviation are not erected in the vicinity of aerodromes and proposed aerodromes.

ICAO Annex 14 specifically addresses the issue of wind turbines. Annex 14 includes a provision for an aeronautical study as to the need, or otherwise, for marking and/or lighting. These standards have been implemented in Ghana by the Ghana Civil Aviation Authority Act, 2004, Act 678 and Part 27 (the Airports (Protection of Airspace)) of the Ghana Civil Aviation (Aerodrome) Regulations, 2011, L.I. 2004.

These guidelines will have the additional benefit of being applicable in areas away from airports to address the risk posed by wind farms to air navigation in those areas. These guidelines will also ensure that the Authority can adequately examine and address the risk to aviation safety from proposed wind turbine farms at the planning stage. This will enable the use of wind energy to continue to grow, while ensuring the protection of aviation safety.

These guidelines rely on an approach of risk identification and management to ensure risks to aviation are minimized in the most effective and efficient manner possible. It is not the intention to adopt an overly restrictive approach to wind farm development, but rather to ensure risks are identified early and mitigation measures are able to be planned and implemented at an early stage.

Part A of these guidelines refers to Obstruction Evaluation and Airspace Assessments.

Part B of these guidelines refers to the impact Assessments on the CNS facilities

Definitions

For the purpose of these Guidelines the following are definitions of terms used:

Aerodrome means a defined area on land or water (including any buildings, installations and equipment) intended to be used either wholly or in part for the arrival, departure and surface movement of aircraft.

Aircraft operation means the surface movement, takeoff or landing of an aircraft **Airport Master Plan** means a comprehensive study of the airport and typically describes short-, medium-, and long-term plans for airport development. (ICAO Doc 9184 –Airport Planning Manual Part 1)

Airport or airstrip means any landing or takeoff area intended for use by airplanes or other fixed wing type aircraft. An aerodrome includes but is not limited to the following: airport, airstrip, heliport, helistop, vertiport, gliderport, seaplane base, ultralight flightpark, manned balloon launching facility, or other aircraft landing or take off area.

Applicant means each person who proposes to a project or action that requires that the Director General is notified under these Guidelines.

Determination means a decision taken by the Authority.

Director General means the Director General of the Ghana Civil Aviation Authority

Ground level at its site means the highest ground within a 600 m radius of the site.

Heliport means any landing or take off area intended for use by helicopters or other rotary wing type aircraft capable of vertical take off and landing profiles.

Manual of Standards means the document called 'Manual of Standards (MOS) – Aerodromes" published by the Authority, as in force from time to time.

Movement area means that part of an aerodrome to be used for the take-off, landing and taxiing of aircraft, consisting of the manoeuvring area and the apron(s).

Navigable airspace means the airspace above the minimum altitudes of flight prescribed by the Regulations and includes airspace needed to ensure safety in the take off and landing of aircraft.

Obstacle. All fixed (whether temporary or permanent) and mobile objects, or parts thereof, that:

a) are located on an area intended for the surface movement of aircraft; or
b) extend above a defined surface intended to protect aircraft in flight; or
c) stand outside those defined surfaces and that have been assessed as being a hazard to air navigation (Annex 14 — Aerodromes, Volume I — Aerodrome Design and Operations).

Obstacle limitation surface means airspace defined around an aerodrome that enables operations at the aerodrome to be conducted safely and that prevents the aerodrome from becoming unusable by the growth of obstacles around the aerodrome

Offshore wind farm or offshore wind energy means the use of wind farms constructed offshore, usually on the continental shelf, to harvest wind energy to generate electricity.

Planning Authority means a local authority

Private use means available for use by the owner only or by the owner and other persons authorized by the owner.

Private use of public lands means that the landing and take off area of the proposed aerodrome is publicly owned and the applicant is a non-government entity, regardless of whether that landing and take off area is on land or on water.

Public use means available for use by the general public without a requirement for prior approval of the owner or operator.

Proponent means each person who proposes to a project or action that requires that the Director General is notified under these Guidelines.

Safety means the state in which risks associated with aviation activities, related to, or in direct support of the operation of aircraft, are reduced and controlled to an acceptable level.

Safety area means a defined area comprised of either a runway or taxiway and the surrounding surfaces that is prepared or suitable for reducing the risk of damage to aircraft in the event of an undershoot, overshoot, or excursion from a runway or the unintentional departure from a taxiway.

Standards for aerodromes mean those standards set out in the Manual of Standards.

Safety assessment means an element of the risk management process of an SMS that is used to assess safety concerns arising from, inter alia, deviations from standards and applicable regulations, identified changes at an aerodrome or when any other safety concerns arise.

Safety risk means the predicted probability and severity of the consequences or outcomes of a hazard.

Traffic pattern means the traffic flow that is prescribed for aircraft landing or taking off from an aerodrome, including departure and arrival procedures utilized within a 5-mile radius of the aerodrome for ingress, egress, and noise abatement.

Wind farm or wind development means a group of wind turbines in the same location used to produce electricity. A large wind farm may consist of several hundred individual wind turbines and cover an extended area of hundreds of acres of land.

Acronyms

ATC – Air Traffic Control

CAA - Civil Aviation Authority

GCAA – Ghana Civil Aviation Authority

GCARs – Ghana Civil Aviation Regulations

GA - General Aviation

ICAO - International Civil Aviation Organization

ILS - Instrument Landing System

IFR – Instrument Flight Rules

LOC – Localizer

LVO – Low Visibility Operations

LVP – Low Visibility Procedures

km – Kilometer

m – Meter

MOS – Manual of Standards

MoD - Ministry of Defence

OLS - Obstacle Limitation Surface

VFR – Visual Flight Rules

VMC – Visual Meteorological Conditions

PANS-OPS - Procedures for Air Navigation Services –Operations

PA - Planning Authority

WT - Wind Turbine

GUIDELINES ON WIND TURBINE DEVELOPMENT NEAR AIRPORTS AND AERONAUTICAL FACILITIES.

1.0 Purpose

1.1 The primary goal of these Guidelines is to facilitate the development of wind energy whilst ensuring that the interest of civil aviation is recognized and aviation safety interests are kept paramount.

1.2 These Guidelines are intended to provide information to proponents of wind farms and planning authorities to help identify any potential safety risks posed by wind turbine and wind monitoring installations from an aviation perspective.

1.3 These Guidelines also provide specific advice on measures to reduce hazards to aviation, and how to implement them.

2.0 Scope and Applicability

2.1 These Guidelines shall provide general information and advice to:

a. proponents of wind farms (including single wind turbines); and

b. planning authorities with jurisdiction over the approval of such structures.

2.2 These Guidelines shall apply to:

a. A single wind turbine, or

b. A group of wind turbines, referred to as a wind farm, which may be spread over a relatively large area.

c. Wind monitoring towers

3.0 General

3.1 The height of a wind turbine is defined as the maximum height reached by the tip of the turbine blades at their highest point above ground level.

3.2 The marking and lighting described in this document addresses aviation requirements only.

3.3 For offshore wind farms, separate lighting and marking may be required for the safety of marine navigation.

3.4 Where GCAA deems it appropriate, critical simulations and or computer modelling shall be conducted.

4.0 Notification of GCAA of A Wind Farm Proposal

4.1 Prior to approaching the local planning authority for approval of a proposal to construct a wind turbine or wind turbine farm, the proponent shall inform the GCAA in writing of their intention to develop or construct a wind turbine or wind turbine farm.

4.2 The GCAA shall will object to wind farms if the Authority believes that the wind farm will in any way compromise safety.

4.3 There are two ways in which the construction of a wind turbine or wind farm may impact upon aviation operations:

a. The physical obstruction caused by a tall structure (Part A); and

b. The effects that the supporting structure and rotating turbine blades can have on CNS systems (including radar) and other equipment, referred to as “technical sites” (Part B).

PART A- OBSTRUCTION CAUSED BY A TALL STRUCTURE

5.0 Obstruction Evaluation and Airspace Assessments.

5.1 All proponents of wind turbines or wind farms shall notify the Ghana Civil Aviation Authority (GCAA) of their plans to construct a wind turbine or wind monitoring tower.

5.2 The GCAA shall be notified through an official letter to the Director General to enable GCAA Safety Inspectors conduct the needed safety risk assessment of proposed wind turbines.

5.3 Operators of aerodromes are required to notify GCAA if they become aware of any development or proposed wind turbine construction near the aerodrome that is likely to create an obstacle to aviation, or if an object will infringe the Obstacle Limitation Surfaces (OLS) or Procedures for Air Navigation Services –Operations (PANS-OPS) surfaces of an aerodrome.

5.4 The GCAA in coordination with other stakeholders shall evaluate to determine if there is an impact on published flight procedures for the aerodrome.

6.0 Consultation

6.1 Consultation with aviation stakeholders in the early stages of planning for wind turbine developments shall include:

a. early identification of any nearby certified, registered, authorized or proposed aerodromes;

b. immediate consultation with any nearby aerodrome owners;

c. preliminary assessment by an aviation consultant of potential issues;

d. confirmation of the extent of the OLS for any nearby aerodromes;

e. registration of all wind monitoring towers on the proposed wind turbine site (s);

f. consultation with local agricultural pilots and nearby unregistered airstrip owners; and

g. consultation with GCAA.

7.0 Risk Assessment

7.1 Following preliminary assessment by an aviation consultant of potential issues, proponents shall commission a formal assessment of any risks to aviation safety posed by the proposed wind turbine development. This assessment shall address any issues identified during stakeholder consultation.

7.2 The risk assessment shall address the merits of installing obstacle marking or lighting.

7.3 The risk assessment shall determine whether or not a proposed structure will be a hazardous object.

7.4 GCAA may determine, and subsequently advise a proponent and relevant planning authorities that the structure(s) has been determined as:

a. hazardous, but that the risks to aircraft safety would be reduced by the provision of approved lighting and/or marking; or

b. hazardous and should not be built, either in the location and/or to the height proposed as an unacceptable risk to aircraft safety will be created; or

c. not a hazard to aircraft safety.

7.5 If the Authority determines that the proposal is hazardous and should not be built, planning authorities shall not approve the proposal.

7.6 The Authority shall object to the proposal where it is determined that a wind turbine will penetrate a PANS-OPS surface.

7.7 Planning decision makers shall not approve a wind turbine to which GCAA has objected.

7.8 In the case of military aerodromes, GCAA in coordination with the Ministry of Defence shall conduct a similar assessment to the process described above if required and may object to a proposal if it is determined that such a construction will adversely impact Communications, Navigations or Surveillance (CNS) infrastructure.

7.9 The GCAA will provide detailed advice to proponents on request regarding the requirements that a risk assessment process must meet from the CNS perspective.

8.0 Marking of Wind Turbines in The Vicinity of an Aerodrome

8.1 Rotor blades, nacelle and upper two thirds (2/3) of the supporting mast of wind turbines shall be painted white, unless otherwise indicated by an aeronautical study.

8.2 Notwithstanding section 9.1 below, other colours shall be acceptable by the GCAA, unless the colour of the turbine is likely to blend in with the background.

9.0 Lighting of Wind Turbines in The Vicinity of an Aerodrome

9.1 Where a wind turbine proposed development site will penetrate the OLS of an aerodrome, the proponent shall conduct an aeronautical risk assessment.

9.2 The risk assessment shall be conducted by a suitably qualified person(s) and shall examine the effect of the proposed wind turbines on the operation of aircraft.

9.3 The study shall be made available to GCAA to review and evaluate the assessment of any potential risk to aviation safety, if applicable.

9.4 The GCAA may determine that the proposal is:

a. hazardous and should not be built, either in the location and/or to the height proposed, as an unacceptable risk to aircraft safety will be created; or

b. hazardous, but that the risks to aircraft safety would be reduced by the provision of approved lighting and/or marking.

10.0 Lighting of Wind Turbines Not in The Vicinity of an Aerodrome, With A Height of 150m or More

10.1 Where a wind turbine is 150m or taller in height is proposed away from aerodromes, the proponent shall conduct an aeronautical risk assessment.

10.2 The risk assessment, to be conducted by a suitably qualified person, shall examine the effect of the proposed wind turbines on the operation of aircraft.

10.3 The study must be submitted to GCAA to enable an assessment of any potential risk to aviation safety.

10.4 GCAA may determine that the proposal is:

a. hazardous, but that the risks to aircraft safety would be reduced by the provision of approved lighting and/or marking; or

b. not a hazard to aircraft safety.

11.0 Obstacle Lighting Standards for Wind Turbines

11.1 When lighting has been recommended by GCAA to reduce risk to aviation safety, medium-intensity obstacle lights shall be used. Where used, lighting on wind farms shall be installed:

a. to identify the perimeter of the wind farm;

b. maximum spacing of 900m between lights along the perimeter, unless an aeronautical study shows that a greater spacing can be used;

c. where flashing lights are used, they flash simultaneously; and

d. within a wind farm, any wind turbines of significantly higher elevation are identified wherever located.

11.2 To minimise the visual impact on the environment, obstacle lights may be partially shielded, provided it does not compromise their operational effectiveness.

11.3 Where obstacle lighting is provided, lights shall be operated at night, and at times of reduced visibility.

11.4 All obstacle lights on a wind farm shall be turned on simultaneously and off simultaneously.

11.5 Where obstacle lighting is provided, proponents shall establish a monitoring, reporting and maintenance procedure to ensure outages, including loss of synchronisation, are detected, reported and rectified. This would include making an arrangement for a recognised responsible person from the wind farm to notify the relevant section of the GCAA, to enable the Authority advise pilots of light outages.

12.0 Alternatives to Fixed Obstacle Lighting

12.1 In some circumstances, it may be feasible to install obstacle lights that are activated by aircraft in the vicinity. This involves the use of radar to detect aircraft within a defined distance that may be at risk of colliding with the wind farm. When such an aircraft is detected, the wind farm lighting is activated. This option may allow aviation safety risks to be mitigated where obstacle lighting is recommended while minimising the visual impact of the wind farm at night.

13.0 Marking and Lighting of Wind Monitoring Towers

13.1 Wind farm proponents shall take appropriate steps to minimise such hazards associated with wind monitoring towers for anemometers and the provision of meteorological readings, particularly in areas where aerial agricultural operations occur. Measures to be considered shall include:

a. the top one- third (1/3) of wind monitoring towers to be painted in alternating contrasting bands of colour.[1]

b. In areas where aerial agriculture operations take place, marker balls or high visibility flags can be used to increase the visibility of the towers;

c. marker balls or high visibility flags or high visibility sleeves placed on the outside guy wires;

d. ensuring the guy wire ground attachment points have contrasting colours to the surrounding ground/vegetation; or

e. a flashing strobe light during daylight hours.

14.0 Reporting of Structures Less Than 150m in Height

14.1 All prospective proponent(s) shall notify GCAA in writing, of any proposed wind turbine or wind monitoring tower in all parts of the country for the purposes of safety risk assessment.

14.2 This information shall form part of the data in the GCAA National Obstacle database of tall structures maintained by the GCAA.

15.0 Voluntary Provision of Obstacle Lights

15.1 Pilots conducting low flying operations such as aerial agricultural spraying, aerial mustering, power line inspection, helicopter operations including search and rescue, some sports

[1] Examples of effective measures can be found in the Aerodrome Manual of Standards of the GCARs Aerodromes.

aviation, shall be required to have the necessary special training and shall be required to take obstacles into account when planning and conducting low flying operations.

15.2 In making decisions regarding the marking and lighting of wind farms and wind monitoring towers, wind farm operators shall take into account their duty of care to pilots and owners of low flying aircraft.

16.0 Turbulence

16.1 The GCAA shall inform of all representatives of aerial agriculture, sport aviation and general aviation in the vicinity of the wind farm of this risk by notification in writing where approval is granted for a turbine which may:

a. create turbulence which is noticeable up to 16 rotor diameters from the turbine; or

b. in the case of larger wind turbines, a turbine with a diameter of 125 metres with which turbulence may be present two kilometres downstream.

PART B – IMPACT ON COMMUNICATION NAVIGATION SURVEILLANCE (CNS) FACILITIES.

17.0 General

17.1 Where a proposed development falls within a frame or volume a technical area to be safeguarded against buildings or other structures erected within the safeguarded area which may cause interference to the signal radiated by the station, a further analysis or reasoned outright rejection shall be considered by the GCAA.

17.2 The potential impacts of wind farms on air traffic management are likely to affect the following systems:

a. Air Traffic Control Radars i.e. Primary Surveillance Radar and Secondary Surveillance Radar.

b. Navigation Aids (Navaids).

18.0 Air Traffic Control Radars

18.1 When a wind turbine is located close to a radar (less than 15 km for a PSR, less than 16 km for an SSR) a detailed impact assessment shall be undertaken unless the potential impact of the wind turbine does not cause an operational issue (e.g. if the wind turbine is not located under an ANSP operational area).

18.2 A detailed impact assessment shall, address the following topics.

19.0 PSR shadowing

19.1 The detailed assessment shall include:

a. A calculation of the (two-way) attenuation caused by the wind turbines in three dimensions

b. The impact in the three dimensions of this attenuation on the radar detection performance.

19.2 The detailed assessment shall address this topic in terms of impact on the PSR probability of detection.

19.3 PSR False Target Reports (Due to Echoes Caused by Wind Turbines)

19.3.1 The detailed assessment shall include:

a. A calculation of the amount of energy reflected back to the radar by the wind turbine taking into account:

(i) Different nacelle orientations,
(ii) Different blade orientations,
(iii) Different radar frequencies,
(iv) Different surface conditions (wet, moisture, etc), materials, etc are correctly incorporated in the study,
(v) The different elements of the wind turbine located at different heights,
(vi) Appropriate terrain attenuation calculation based on the use of an agreed tool using appropriate parameters.

b. The impact of this energy in terms of false target reports taking into account:
(i) Radar receiver capability;
(ii) Radar signal processing capability; and (iii) Radar data processing capability.

19.3.2 The detailed assessment shall address this topic and assess the region where these false target reports may appear and their density.

19.4 PSR False Target Reports (Due to Secondary or Indirect Reflections from The Wind Turbines)

19.4.1 In addition to the case reported above, another potential mechanism providing spurious false target reports is through reflection of true target echoes on wind turbines and through reflection of wind turbine echoes on aircraft.

19.4.2 Four different cases of reflections may happen; they are summarized below and are further described in Annex – C.

19.4.3 True aircraft echoes reflected from the wind turbine: aircraft located in the vicinity of a wind turbine (for cases 1 and 2) or in the vicinity of the radar (only for case 2) will produce a genuine target report at their actual position and may produce a reflected target report in the azimuth of the wind turbine.

19.4.4 Wind turbine echoes reflected to the aircraft: aircraft located in the vicinity of a wind turbine or radar (both cases 3 and 4) will produce a genuine target report at their actual position and may produce a second, reflected target report in the azimuth of the aircraft.

19.4.5 The detailed assessment of false target reports due to reflections shall include:

a. A calculation of the aircraft locations where reflections can occur.
b. A calculation of where the corresponding false target reports due to reflections will be located.

19.5 PSR Range and Azimuth Errors

19.5.1 When there is a small path difference between the direct and reflected signals the received signal will be a combination of both, which can result in a range and/or bearing measurement error. This effect may occur to targets located further away than the wind turbine and in the same azimuth region. The detailed assessment shall address this topic and assess the region where these errors may occur and the impact on PSR position accuracy performance in this region.

19.6 PSR Processing Overload

19.6.1 Where the number of PSR echoes due to wind turbines (clutter and reflections) is too high, the plot processor may need to apply anti-overload techniques.

19.6.2 Similarly, if the number of false plots due to wind turbines is too high, the tracker may need to apply overload prevention techniques. Both may have an operational impact (e.g. reducing the operational capability of the radar).

19.7 PSR Receiver Saturation

19.7.1 Where the amount of energy reflected back to the radar from the wind turbine can be so large that it saturates the radar receiver, a detailed assessment shall address this topic in terms of impact on the PSR probability of detection.

19.8 SSR Probability of Detection and Probability of Mode A and Mode C Code Detection

19.8.1 Where a wind turbine is located close to an SSR, that the detection of aircraft located close to the wind turbine and within the same azimuth may be impacted,

the impact shall be calculated in the three dimensions independently for the uplink (aircraft located in the shadow region behind the wind turbine) and the downlink transmissions (SSR located in the shadow region behind the wind turbine).

19.8.2 In the case of the downlink transmission, the aircraft position detection may not be affected whereas the Mode A or Mode C code detection may be affected.

19.8.3 The detailed assessment shall address this topic and shall predict the impact in the three dimensions on position detection and Mode A and C code detection performance.

19.9 SSR False Target Reports

19.9.1 Where it is deemed possible that SSR false target reports may appear due to reflection on the wind turbine of the uplink signal, of the downlink signal and/or of both, a detailed assessment shall address this topic and shall predict where the false target reports will be located.

19.10 SSR 2D Position Accuracy

19.10.1 SSR bearing errors may occur when there is a small path difference between the direct and reflected signals. In the case where there is a large path difference the two can be separated which can lead to a false target. Effects can be seen in MSSR, Mode S and classical 'sliding window' SSR systems. This effect may occur to targets located further away than the wind turbine and in the same azimuth region. A detailed assessment shall address this topic and shall predict the impact in the three (3) dimensions on the SSR position accuracy performance.

19.10.2 In the case of a Mode S radar a single reply will be deemed sufficient to generate a target report.

19.11 Primary Surveillance Radar (PSR)

19.11.1 No wind turbine(s) shall be mounted within 0 -500 m of the Radar site. This is the safeguarded zone of the radar system.

19.11.2 The PSR safeguarding range where no wind turbine shall be built is derived from the recommendations provided in ICAO's Guidance Material on Managing

Building Restricted Areas[2], which is applicable to any obstacle (r: radius of the first cylinder on figures 2.1 and 2.2).

19.11.3 From 500m – 15km and within the radar line of site, a wind turbine of height 30m-200m with horizontal rotational axis shall be mounted only after a detailed technical and operational assessment has been carried out.

19.11.4 A simple assessment shall be conducted before a wind turbine can be installed further than 15km but within maximum instrumented range and in radar line of sight.

19.11.5 No assessment shall be required anywhere within maximum instrumented range but not in radar line of sites / anywhere outside maximum instrumented range.

19.12 Secondary Surveillance Radar (SSR)

19.12.1 No wind turbine(s) shall be mounted within 0 -500 m of the radar site. This is the safeguarded zone of the radar system.

19.12.2 The SSR safeguarding range where no wind turbine shall be built is derived from the recommendations provided in ICAO's Guidance Material on Managing Building Restricted Areas[3] which is applicable to any obstacle (r: radius of the first cylinder on figures 2.1 and 2.2).

19.12.3 From 500m – 16km but within maximum instrument range and in the radar line of site, a wind turbine of height 30m-200m with horizontal rotational axis shall be mounted only after a detailed technical and operational assessment has been carried out.

19.12.4 No assessment shall be required for areas further 16km or areas not in radar line of sight.

20.0 NAVAIDS

20.1 Navigation Systems and Multipath Interferences

20.1.1 Navigation and landing systems are usually susceptible to multipath interferences from large structures located in proximity to the radiating source

[2] EUR 015 Document, November 2015, Third Edition
[3] supra

of the systems. Interference could be caused by path-obstruction-shadowing, reflection, scattering or re-radiation.

20.1.2 The Navigation Aids include:

a. Non-Directional Beacons (NDB)

b. Distance Measuring Equipment (DME)

c. Instrument Landing System (ILS)

d. Microwave Landing System (MLS)

e. VHF Omni-directional Radio Range (VOR) and

f. Tactical Air Navigation (TACAN)

20.1.3 The effect of multipath interference can sometimes result in out-of-tolerance conditions for a navigation aid or a landing system of interest.

20.2 VOR Siting Criteria

20.2.1 To safeguard the operation of a VOR, the siting guidelines criteria as stated in Annex 10[4] must be satisfied.

20.2.2 To ensure that VOR facilities will experience no significant degradation of performance due to the presence of wind- turbine generators, the GCAA shall ensure that the generators are sited in accordance with siting criteria for objects near VOR and other Navigation systems.

20.3 Standard Guidelines for Objects Near VOR Facilities

20.3.1 Only crop raising and grazing are allowed within 1000 feet (300m) of the VOR except at mountain top sites where these activities must be restricted to area below and off the counterpoise.

20.3.2 Single trees of up to 30 feet are tolerated beyond 500 feet from the central antenna.

[4] Sixth Edition-2006

20.3.3 The height of wire lines and fences shall not subtend a vertical angle of more than 1.5 degrees or extend more than 0.5 degree above horizontal as measured from the antenna array.

20.3.4 Overhead power and control lines may be installed beyond 600 feet of the VOR antenna but must remain essentially radial.

20.3.5 No group of trees shall subtend a vertical angle greater than 2 degrees or be situated within 300m (1000ft) of the station

20.3.6 No structures shall subtend a vertical angle greater than 1.2 degrees or be situated within 150m (500ft) of the station.

20.3.7 No ground, trees, power lines, buildings or objects between 45m (150ft) and 360m (1200ft) shall be within optical line of sight of the antenna array system.

20.3.8 No structures shall be permitted within 1000 feet of the antenna.

20.3.9 No structures should subtend a vertical angle greater than 1.2 degrees or be situated within 150 m (500ft) of the station.

20.3.10 The GCAA may give consideration to wooden structures with negligible metallic content if subtending vertical angles are less than 2.5 degrees.

20.4 A proposed wind farm shall be assessed to a distance of 15 km from the VOR facility, with special attention to any turbines within the Building Restricted Area (BRA) delimited by the following criteria:

20.4.1 any turbine infringing a 600 m distance (r) or a 1° slope from the centre of the antenna at ground level (α) to a distance of 3 km (R), or a 52 m horizontal surface (h) from a distance of 3 km (R) to 15 km (j). [5]

20.5 Siting Criteria for Localizer

20.5.1 Environmental factors which shall be considered when siting a localizer facility include but not be limited to;

[5] See Appendix B for illustration.

a. large building, power lines,

b. metallic objects, fences,

c. cylindrical structures such as towers, fuel tanks and terrain.

20.5.2 Where Localizer siting criteria does not provide any criteria to evaluate such clusters of wind turbines sited near a Localizer, critical simulations and or computer modelling shall be conducted in addition to the siting guidance criteria.[6]

20.6 Coverage-Localizer[7]

20.6.1 The localizer coverage sector shall extend from the centre of the localizer antenna system to distance of:

a. 46.3km (25NM) within plus or minus 10 degrees from the front course line.

b. 31.5km (17NM) between 10 degrees and 35 degrees from the front course line.

c. 18.5km (10NM) outside of plus or minus 35 degrees if coverage is provided;

20.6.2 Notwithstanding Clause 20.6.1 above, where topographical features dictate or operational requirement permit, the limit may be reduced to 33.3km (18NM) within the plus or minus 10-degree sector and 18.5km within the remainder of the coverage when alternative navigational facility provide satisfactory coverage within the intermediate approach area.

20.6.3 The localizer signal shall be receivable at the distances specified at and above a height of 600m (200ft) above the elevation of the threshold, or 300m (1000ft) above the elevation of the highest point within the intermediate and final approach areas, whichever is higher. Such signal shall be receivable, to a distance specified by the GCAA, up to a surface extending outward from the localizer antenna and inclined at 7 degrees above the horizontal.

[6] As stipulated by ICAO-Aeronautical Telecommunications, volume 1-Radio Navigation Aids, Sixth Edition, July 2006, page ATTC 2 – ATTC-50. Further guidance is given in ICAO European Document 015; 2009

[7] Guidance material on localizer coverage is given in 2.1.11of Attachment C (ATTC-13 to ATTC-14, Annex 10, Aeronautical Telecommunications, volume 1 Radio Navigation Aids, Sixth Edition-July 2006)

20.7 Glide Path

20.7.1 The proponent shall satisfy the Siting guidance criteria in accordance with GCAA Regulations and Annex 10.[8]

20.8 **Coverage -Glide Path**

20.8.1 The proponent shall provide signals sufficient to allow satisfactory operation of a typical aircraft installation in the sector of 8 degrees in Azimuth on each side of the centre line of the ILS glide path, to a distance of at least 18.5 km (10NM) up to 1.7 and down to 0.45 above the horizontal or to such lower angle, down to 0.3 as required to safeguard the promulgated glide path intercept procedure.

20.8.2 The developer shall satisfy the Siting guidance criteria as stated in Annex 10.

20.9 **Distance Measuring Equipment**

20.9.1 The developer shall satisfy the Siting guidance criteria as stated in Annex 10.

20.10 Non-Directional-Beacon:

20.10.1 The developer shall satisfy the Siting guidance criteria as stated in Annex 10.

[8] 20.1.1 Aeronautical Telecommunications, volume 1-Radio Navigation Aids, Sixth Edition, July 2006, page ATTC-2 – ATTC-50. DME: ATTC 68 –ATTC 82, NDB: ATTC58- ATTC 68

APPENDIX A

Figure 2.1: Omni - Directional BRA Shape (three dimensional representation)

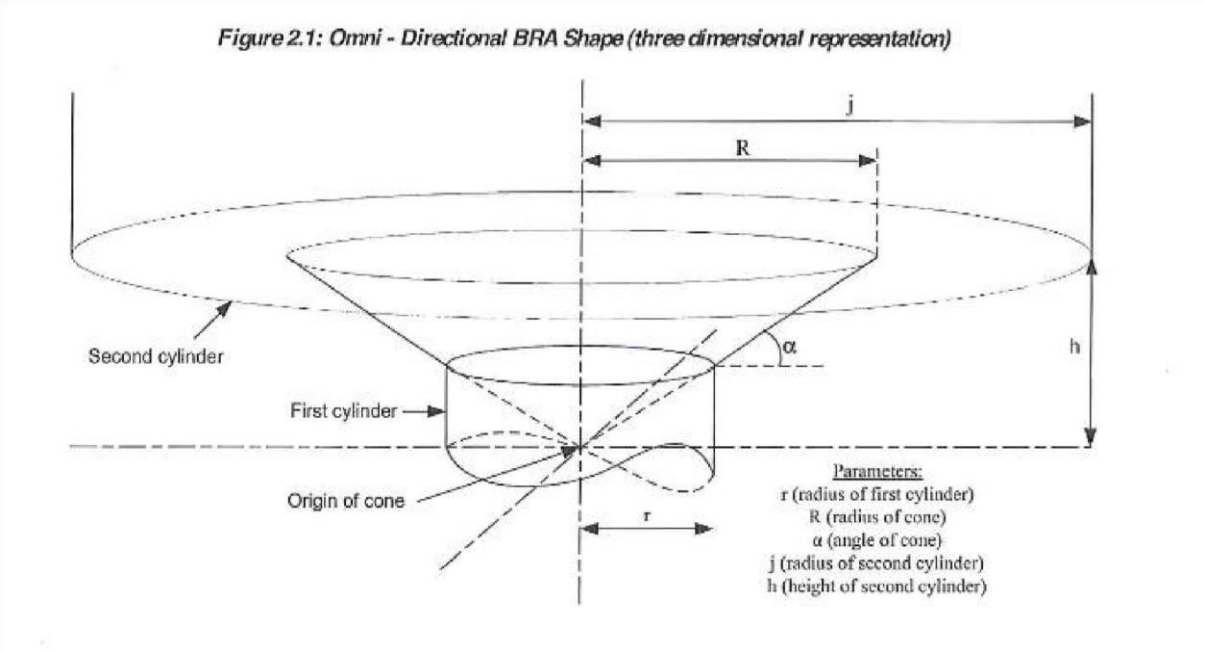
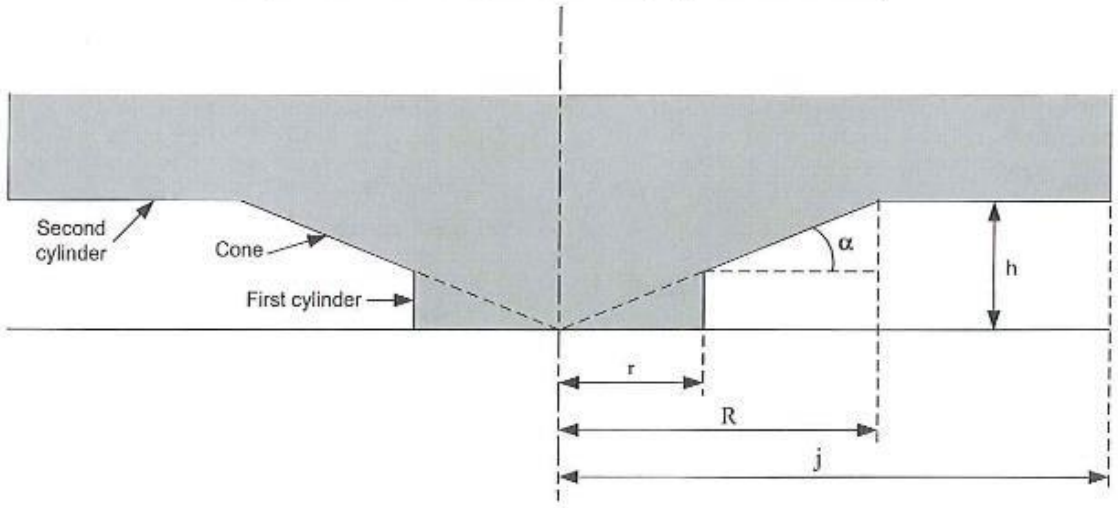


Fig. 2.1 shows the BRA shape for Omni-directional navigational services, such as VOR, and the dimensions of this shape for the VOR case. The heights and surfaces specified for wind turbines apply to blade tip in vertical. Where the terrain cannot be considered to be flat, for example in the case of sloping terrain, then all wind turbine proposals should be assessed out to the full radius of cylinder j or the BRA adapted to the actual terrain (see Fig.2.2 below).

Figure 2.2: Omni - Directional BRA Shape (side elevation view)



APPENDIX B

Table 1: Harmonised guidance figures for the omni-directional navigational facilities in accordance with Figures 2.1 and 2.2

Type of navigation facilities	*Radius (r – Cylinder) (m)*	*Alpha (a – cone) (°)*	*Radius (R- Cone) (m)*	*Radius (j – Cylinder) (m) Wind turbine(s) only*	*Height of cylinder j (h -height) (m) Wind turbine(s) only*	*Origin of cone and axis of cylinders*
DME N	300	1.0	3000	N/A	N/A	Base of antenna at ground level
VOR	600	1.0	3000	15000	52	Centre of antenna system at ground level
Direction Finder (DF)	500	1.0	3000	10000	52	Base of antenna at ground level
Markers	50	20.0	200	N/A	N/A	Base of antenna at ground level
NDB	200	5.0	1000	N/A	N/A	Base of antenna at ground level
GBAS ground Reference receiver	400	3.0	3000	N/A	N/A	Base of antenna at ground level
GBAS VDB station	300	0.9	3000	N/A	N/A	Base of antenna at ground level
VDB station monitoring station	400	3.0	3000	N/A	N/A	Base of antenna at ground level

- The heights and surfaces specified for wind turbine(s) apply to the tip of the turbine blade when vertical. Where the terrain cannot be considered to be flat, for example in the case of sloping terrain, then all wind turbine proposals should be assessed out to the full radius of cylinder j or the BRA adapted to the actual terrain.

APPENDIX C

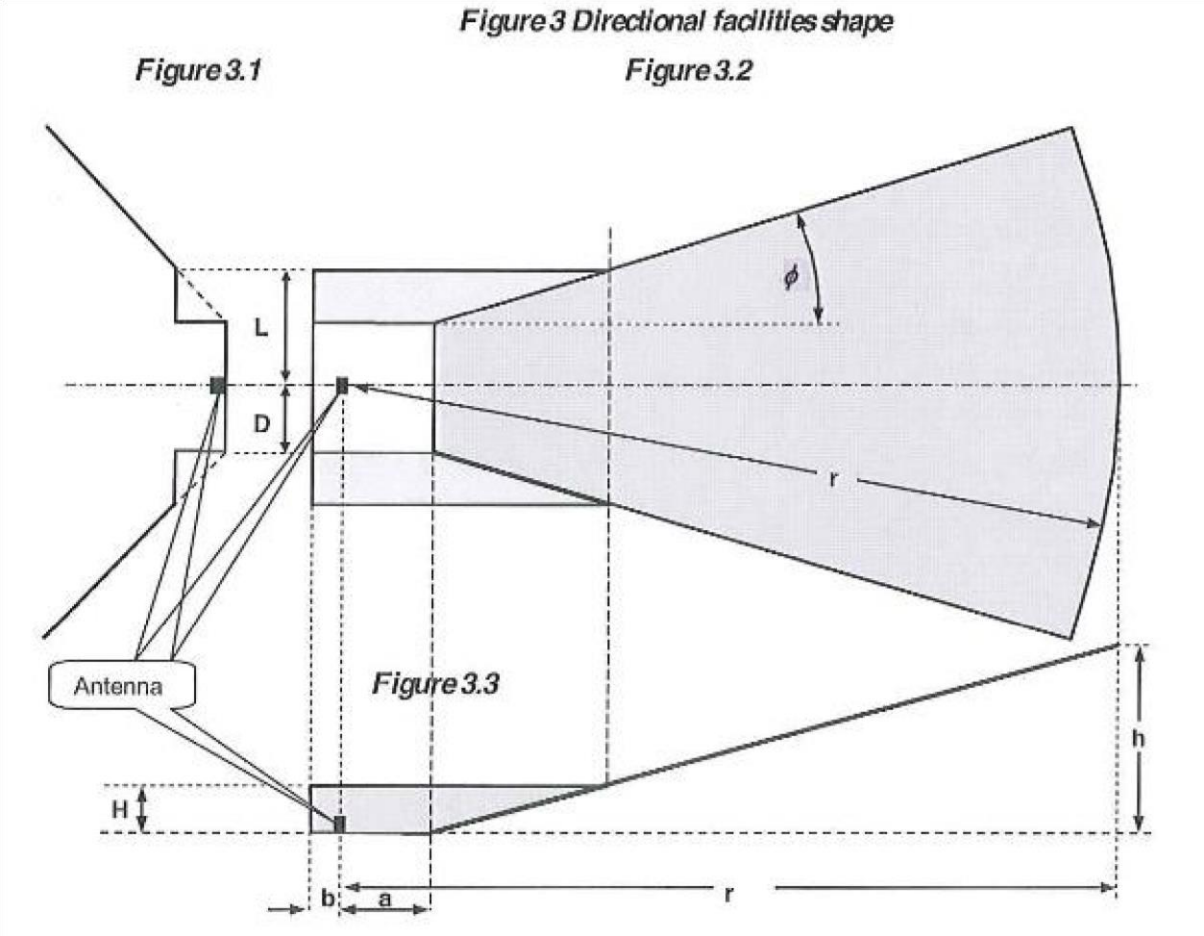


Figure 3 Directional facilities shape
Figure 3.1
Figure 3.2
L
D
ϕ
r
Antenna
Figure 3.3
h
H
b
a
r

APPENDIX D

Table 2: Harmonised guidance figures for the directional navigational facilities in accordance with Figure 3

Type of navigation facilities	A (m)	b (m)	h(m)	r (m)	D (m)	H (m)	L (m)	ϕ (°)
ILS LLZ (medium aperture single frequency)	Distance to threshold	500	70	a+6000	500	10	2300	30
ILS LLZ (medium aperture dual frequency)	Distance to threshold	500	70	a+6000	500	20	1500	20
ILS GP M–Type (dual frequency)	800	50	70	6000	250	5	325	10
MLS AZ	Distance to threshold	20	70	a+6000	600	20	1500	40
MLS EL	300	20	70	6000	200	20	1500	40
DME (directional antennas)	Distance to threshold	20	70	a+6000	600	20	1500	40

Notes:

- The parameters (a) and (b) originate from the base of the antenna and follow the terrain.
- (r) originates from the base of the antenna and is referenced to the horizontal plane.
- ϕ is measured in a horizontal plane.
- Other specific notes pertaining to omni or directional shapes are included in the respective section of the procedure.
- In case of advanced operations supported by either MLS or GNSS, specific adaptation to the respective BRA will have to be made.