

Wind Inspection and Testing Guidelines

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1 SCOPE

These Guidelines provide information on the Inspection and Testing procedures to be carried out by the eligible consumer at the end of the construction of a Wind System, in order to connect it to the Distribution Network in KSA. These Guidelines are providing the technical know-how and knowledge to the test engineers and contractors to help them conducting the commissioning successfully. SEC will never be accounted responsible for checking the execution of the below guidelines, SEC instead will be always interested only in the equipment that would impact the distribution network at the point of connection.

DISCLAIMER
The contractor, consultant and eligible consumer are the ultimate responsible for everything in the REG system and for the commissioning. SEC will inspect and commission these systems according to its internal checklist, focusing only on the components and equipment impacting the distribution network and the connection point.

Referring to the approved WERA regulations and SEC connection process, the inspection and testing are executed in Step 3 named as “REG Connection” phase. SEC’s responsibilities at this stage will be limited to the following:

- Inspect the REG system to verify the correspondence between the REG system and the documentation provided and approved during the Design Document evaluation stage:
  - Agree with the Eligible Consumer on the inspection date
  - Completeness of the documentation and its correspondence with the REG system on-site, as per SEC’s inspection checklist.
  - Inspect the presence of Interface Protection and required switches.
  - Witness Compliance test to be performed if necessary, during cold commissioning.
  - Temporary connection granted (known as “Limited Operational Notification”).
- Generation Meter installation if all tests have a positive outcome.

During REG Energization & Operation phase, SEC will have the right to witness the commissioning tests only if deemed necessary. SEC eventually will be responsible for issuing the “Final Operation Notification” and If deemed necessary, SEC is entitled to ask the Eligible Consumer to sign a REG System Operational Agreement. SEC will also check the commissioning report following SEC’s commissioning checklist.

2 COMPANION DOCUMENTS

The documents listed hereinafter have to be considered a compendium of the current document. Therefore, they should be carefully read in addition to this.

[1] CESI_SEC-DREG Wind Best Practice for Design_v3.0 Final.docx
[2] CESI_SEC-DREG Wind Component Specifications_v3.0 Final.docx
[3] CESI_SEC-DREG Wind Connection Guidelines v3.0 Final.docx
[4] CESI_SEC-DREG Wind Health and Safety Requirements_v3.0 Final.docx
[5] CESI_SEC-DREG Wind Inspection and Testing Checklists v3.0 Final.docx
[6] CESI_SEC-DREG Wind Manual for the maintenance_v3.0 Final.docx

[7] CESI_SEC-DREG Wind Standards for Connection_v3.0 Final.docx

3 TERMS AND DEFINITIONS

Active power – Active Power is the real component of the apparent power, expressed in watts or multiples thereof (e.g. kilowatts (kW) or megawatts (MW)). In the text this will be generically referred as P or Pnom in case of nominal active power of equipment.
Apparent power – Is the product of voltage (in Volt) and current (in Ampere). It is usually expressed in kiloVolt-Ampere (kVA) or MegaVolt-Ampere (MVA) and consists of a real component (Active Power) and an imaginary component (Reactive Power). In the text this will be generically referred as S or Sn in case of rated apparent power of equipment.
Connection Point/ Point of Connection (PoC) - The physical point at which User's Plant or apparatus is joined to the Distribution System.
Eligible Consumer – Any Person supplied with electricity services for his own consumption. In this context, this term will also be used to refer to a User owning a Wind System. This term has also the same meaning of Customer, as defined in the Distribution Code. As per WERA Regulations, a Consumer is considered Eligible when it meets both the requirement of the same Regulations and the Connection Conditions as defined in the Distribution Code.
Inspection – examination of an electrical installation using all the senses in order to ascertain correct selection and proper erection of electrical equipment.
Interface Protection (IP) - The electrical protection required to ensure that the Wind System is disconnected for any event that could impair the integrity or degrade the safety and reliability of the distribution network.
Power factor (φ) – under periodic conditions, ratio of the absolute value of the active power P to the apparent power S.
Record – data recorded and stored in data log, based on acquired samples
Report – aggregate value based on series of records
Residual current device (RCD) – is a sensitive safety device that switches off when the residual current exceeds the rated value of the device
Sample – data acquired from a sensor or measuring device
Switch – Mechanical device capable of making, carrying and breaking currents in normal circuit conditions and, when specified, in given operating overload conditions. In addition, it is able to carry, for a specified time, currents under specified abnormal circuit conditions, such as short-circuit conditions.
Testing – implementation of measures in an electrical installation by means of which its effectiveness is proved (Note: It includes ascertaining values by means of appropriate measuring instruments, said values not being detectable by inspection).
Verification – all measures by means of which compliance of the electrical installation to the relevant standards are checked.

4 SAFETY ISSUES

4.1 Foreword

This document does not intend to substitute the safety laws and rules in force in KSA as regards to the works on electric, mechanical and civil installations[1]. Its purpose is to integrate the existing rules with some indications, which are focused on particular safety issues specifically related to Wind Turbine Systems. In this context, it is important to emphasize that only qualified persons with specific expertise, knowledge and experience can work safely on live parts, and can successfully carry out electric interventions under voltage.

4.2 Hazards and safety measures

The on-site test, particularly on electrical installations, is a specific task that is under the responsibility of the Test Engineer. Hence, he/she must be aware of the main details of such electrical tests, and the related hazards, according to the laws and rules in force in KSA. The experience required to the Test Engineer and the description of his/her activities are provided below.
In particular, the construction of medium and large scale Wind Turbine Systems is recognized as the most complicated and most dangerous stage in wind turbines life cycle, as it involves the installation of major components, including the tower foundation, and the turbine assembly. During this stage the heavy lifting of turbine components and the development of multiple tasks in quick succession should be carefully developed, since they are characterized by many safety issues. This is the most personnel intensive phase in the development and operation of a wind turbine system, although the number of required workers sensibly depend on the system size and complexity. Finally, it is important to emphasize that the construction activities are performed in windy areas, and that turbine heights are designed such that the blades should be installed where the wind blows most strongly. The safety implications of working at height and the exposure to these high wind conditions need to be carefully considered throughout the construction, testing and commissioning phase.

The protection provisions and the proper PPE are specified in relevant international and local standards. However, it is worth mentioning that when working under voltage, the operator must at least wear the following PPE (see Figure 1):

- A safety helmet made of insulating material with face shield (mainly to protect him/her against electric arcing).
- Arc related PPE and flame-retardant clothing that does not leave uncovered parts of the trunk or limbs.
- Insulating gloves (of appropriate voltage class).
- Safety Glasses for eye protection
- Safety Footwear
- If required, fall arresters' systems and work positioning belts (especially while working at heights)
- If required, hearing Protection by means of standardized ear plugs or earmuffs.

Insulated tools for electrical work are also to be used. An alternative to insulated tools is an insulating mat for electrical purposes, placed beneath the operator.

[1] It is not the responsibility of SEC to check the compliance of the design of the Wind Turbine systems connected to distribution network with the Saudi Building Code

After the electric shock, arcing represents the main danger in electric interventions under voltage. The energy released by electric arcs may cause burns, damage to eyes and skin and this energy increases with the arcing current and the duration of the intervention.
Works under voltage carried out in open air spaces shall be avoided in case of:

- Fog, rain, snow or dust storm, mainly because of the scarce visibility.
- Very low temperatures or strong wind, because of the difficulty to grip and hold tools.
- Thunderstorms, because of the possible over voltages on circuits.

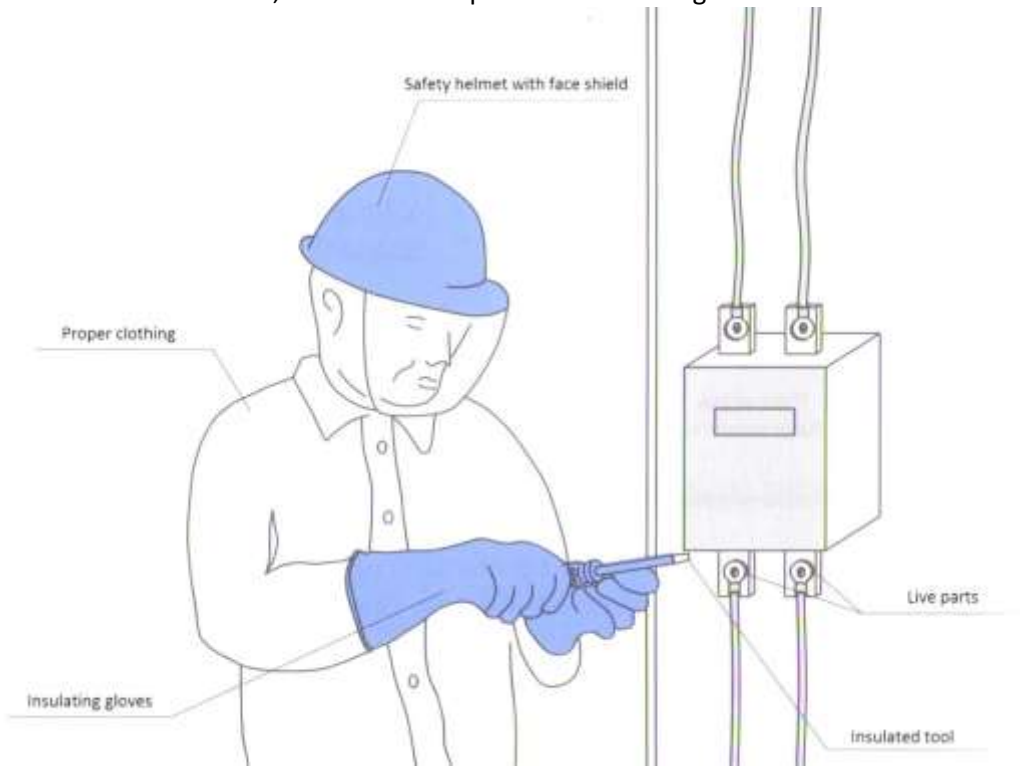

Figure 1 – Main safety measures for works under voltage

4.3 Information from Applicant about Specific Risks on-site and Safety Measures

A form indicating the specific risks and the on-site safety measures (see Annex A – Safety information Form) shall be filled and delivered by the Applicant / Contractor to SEC or to the concerned Authority, before the respective Inspectors visit the site where the Wind Turbine system is located.

4.4 System documentation requirements

The minimum design documentation that needs to be provided with reference to a Wind Turbine System is specified in the Connection Guidelines. The design documentation shall be available on site for consultation by the Inspectors visiting the site where the Wind turbine system is installed.

5 SITE TEST

5.1 Overview

5.1.1 General

The Site Test applies to all Wind Turbine systems regardless their nominal power and voltage connection (i.e. LV or MV). This test is composed by an inspection and a set of tests that should be performed by the Test Engineer appointed by the Applicant.
As a rule, this test begins after the completion of the construction of Wind Turbine system. In all the cases where tests are initiated and completed in a single day it is sufficient to add the date of the day and the time of test initiation and completion, respectively.

5.1.2 Compliance to the Regulations for Electrical Installations in KSA

The Saudi Building Code (SBC) issued by KSA in 2007 specifies proper standards for protection against electric shock, earthing guidelines, protection against lightning strikes, over current and over voltages situations etc. especially for low voltage installations. Wind Turbine Systems are based on generators, which are typically of either Type 1,2, 3 or 4 as specified in the document (*Guidelines for Consumers, Consultants and Contractors to connect a small-scale and medium-scale Wind Turbine system to SEC distribution networks*) whose generation voltage is usually less than 1000V AC.

The Site Test here described encompasses the activities described in Saudi Building Code (SBC) because it is focused on Wind Turbine systems, where the AC sections involving low & medium voltage cabinets switchgear, power and control cables, which must be verified by means of proper procedures that should comply with the most recent experiences and international standards on electric safety.
However, it is always possible to perform, on a voluntary basis, a number of additional verifications and tests according to the Saudi Building Code (SBC).

5.1.3 Basic Tests and Additional tests

The test procedure that is applied to a Wind Turbine System needs to be appropriate to the scale, type, location and complexity of the system under evaluation.
This document defines a Basic test procedure and a number of additional tests that could be performed once the standard sequence is completed.

- Basic tests – The minimum requirement – A standard set of tests that shall be applied to all Wind Turbine System
- Additional tests – Further tests assuming that all Basic tests have already been undertaken. They contain also tests that may be performed in some circumstances. Unless differently agreed, these tests are optional.

5.2 Common requirements

Testing of the electrical installation shall be performed according to the requirements defined in the IEC 60364-6, IEEE 1547 standards and applicable IEC 61400 standards.
Measuring instruments, monitoring equipment, and measuring methods adopted during these tests should comply with the applicable relevant parts of IEC 61557, IEC 61010 and SBC (part 401). If other measuring equipment is used, they should provide an equivalent degree of performance and safety. All tests shall be performed where relevant and should be made according to the sequence listed. In the event of a test indicating a fault, once that fault has been cleared, all previous tests shall be repeated only if the fault influenced the result of these tests.

5.3 Inspection for Wind Turbine Systems (Small Scale and Medium Scale Wind Turbines)

Inspection should precede testing and should normally be performed prior to energizing the wind turbine system. The following items, specific to both off-grid or grid connected Wind Turbine systems, should be assessed during the inspection.

5.3.1 General Verifications (Applicable for all Wind Turbine Systems)

Inspection of the electrical installation of wind turbine system should include at least the following checks:

a) The system has been designed and installed according to the requirements of IEC 60364 and IEC 61400-2 and their latest amendments.
b) Verification of installed system against the As-built drawing, construction manuals and check for deviation with the pre-approved design schemes.
c) Verification of mechanical completion reports and completeness of construction. Listing out any additional or missing installations necessary before commissioning of the wind turbine system.
d) All system components and supporting structures have been selected and erected to withstand the expected external influences such as wind, sandstorms, temperature and corrosion.
e) Verification of functional requirements of protection systems as per IEC 61400-2, which also dictates that there should be a manual shutdown button/switch/lever/etc. and shutdown procedures. The manual shutdown button/switch/lever/etc. should override the automatic control system, and result in a parked turbine for all normal external conditions. After shutdown the turbine shall remain parked until manually returned to operation.
f) Confirm that the equipment and its installation comply with the interconnection installation evaluation in IEEE Std 1547.
g) Protection of assembled components (e.g. IP degree).
h) Visual inspection of electrical power connections in the substations and electrical rooms.
i) Connections of metallic structures and equipment to earthing system (if required).
j) Visually inspect system grounding implementation according to the requirements of IEEE Std 1547.
k) Visually inspect and verify the operation of the isolation device, if required.
l) Verify that polarities, burdens, and ratios of field wired CTs and VTs are correct and in accordance with the design.
m) Through visual inspection, continuity test, or insulation resistance test, verify that field-installed power and control wiring is in compliance with drawings and manufacturer requirements.
n) On three-phase systems, check the phase rotation of both area EPS and DR and verify that they are compatible as installed.
o) Verify functionality of all monitoring provisions required by IEEE Std 1547.
p) Verification of Type test reports of a single Wind Turbine and check the compliance with grid connection requirements as per *Technical Standards for the Connection of wind turbine systems to the LV and MV Distribution Networks of SEC*
q) **Site Responsibility Schedule**. - A Site Responsibility Schedule for every interconnection point should be prepared by the owner of Wind Turbine System, and the following minimal information should be included in the Site Responsibility Schedule: -
    a. schedule of electrical apparatus services and supplies.
    b. schedule of telecommunications and measurement apparatus; and
    c. safety rules applicable to each plant and apparatus.

d. The following information should also be furnished in the Site Responsibility Schedule for each item of equipment installed at the connection site, namely:

i. the ownership of equipment.
ii. the responsibility for control of equipment.
iii. the responsibility for maintenance of equipment.
iv. the responsibility for operation of equipment.
v. the manager of the site.
vi. the responsibility for all matters relating to safety of persons at site; and
vii. the responsibility for all matters relating to safety of equipment at site.

5.4 Inspection for Wind Turbine Systems of installed capacity <02 MW or connected to LV network

5.4.1 Verification of the protection against electric shock

In the Wind Turbine electrical systems at least one of the following measures for protection against electric shock in the AC circuits and DC circuits (wherever applicable) should be adopted:

a) Protective measure provided by extra low voltage (SELV / PELV)
b) Protection by use of class II or equivalent insulation adopted.

Furthermore, it is important to verify that DC cables (wherever applicable especially in off-grid or inverter-based Wind Turbine Systems) and AC cables have been selected, designed and installed so as to minimize the risk of earth faults and short-circuits. This is typically achieved by the use of cables with protective and reinforced insulation (often termed “double insulated”).

Finally, it should be verified that the live parts should be installed inside enclosures or behind barriers providing at least the degree of protection IPXXB or IP2X, and in particular:

a. Verification of suitable precautions to prevent persons or livestock from unintentional touching of live parts.
b. If applicable, it should be ensured that persons will be aware that live parts can be touched through the opening and should not be touched intentionally, and
c. The opening shall be as small as it is consistent with the requirement for proper functioning and for parts replacement.

5.4.2 Verification of the protection against the effects of insulation faults

End-use circuits and equipment should be protected against insulation faults as follows:

a. In TN and TT systems, RCDs with a rated residual operating current ≤300 mA shall be installed. Where resistive faults may cause a fire, e.g. for overhead heating with heating film elements, the rated residual operating current shall be ≤30 mA.
b. In IT systems, it should be installed insulation monitoring devices aimed at continuously monitoring the ground resistance of the whole electrical plant, and/or RCMs (residual current monitoring devices) on the end-use circuits, both with audible and visual signals.

The probability that mineral insulated cables and busbar trunking systems could cause a fire due to insulation faults is considered neglectable, and therefore they could be not protected

5.4.3 Verification of the protection against overcurrent

The protective devices should be capable of breaking any overcurrent up to and including the prospective short-circuit current at the point where the device is installed.

Such protective devices may be:

- circuit-breakers incorporating overload release complying with SASO IEC 61009, SASO IEC 60947-1, SASO IEC 60947-2 or SASO 1349.
- circuit-breakers in conjunction with fuses.
- fuses having fuse-links with characteristics complying with SASO 1899 and SASO IEC 60269-2 or SASO IEC 60269-3.

Inspection of the electrical installation of the Wind Turbine System should include at least the verification of the measures aimed at protecting against overcurrent, and in particular it should be verified that:

a. Collector system cables are sized to accommodate the maximum combined fault current according to IEC 60364.
b. The adopted settings for over current protection at each level of the Balance of Plant are correctly designed.

5.4.4 Verification of earthing and bonding arrangements

Inspection should include the followings checks:

a. Verify that the size of the installed earthing conductor meets the minimum size of commonly used earth electrodes, embedded in soil or concrete as per IEC-60364-5-54 standards.
b. Where an electrode consists of parts that must be connected together, the connection shall be made by means of exothermic welding, pressure clamps, connectors or other suitable mechanical connectors.

5.4.5 Verification of the protection against the effects of lightning and overvoltage

The lightning exposure and the installation environment of small wind turbines are typically very different from those characterizing medium and large wind turbines, hence the corresponding requirements and guidelines for lightning protection will also be quite different. All turbine protection system circuits that could possibly be affected by lightning and other transient overvoltage conditions should be protected according to IEC 61643-11. All surge protection devices used on Small Wind Turbines should comply with the requirements of IEC 61643-11.

Moreover, it is necessary to perform visual inspections aimed at assessing the following conditions:

a. The system is in good repair.
b. There are no loose connections that might result in high-resistance joints.
c. No part of the system has been weakened by corrosion or vibration.
d. All down conductors and earth terminals are intact (non-severed).
e. All conductors and system components are safely fastened to their mounting surfaces and are protected against any possible mechanical displacements.
f. There aren't additions or alterations to the protected structure that would require additional protection.
g. The surge suppression (over voltage) devices are intact and undamaged.
h. The system complies to all the requirements defined in the Chapter 802 of SBC.
i. The lightning protection system and its components complies with the manufacture design.

5.4.6 Verification of the selection and erection of electrical equipment

Inspection should include the following checks:

a. The conductors installed on a Small Wind Turbine should be rated according to the operation conditions characterizing the application domain considering, in particular, the temperature, voltage, current, environmental conditions and exposure to degraders (oil, UV exposure) in accordance with the Clause 13 of IEC 60204-1:2005.

b. The conductors should be installed according to the requirements of the Clause 14 of IEC 60204-1:2005. To this aim, all the mechanical stresses, including those arising from twisting, that can affect the conductor's integrity during installation and operation should be considered and assessed.
c. Armored cables or conduits should be used if there is a probability that rodents or other animals could damage the cables. Underground cables shall be buried at a suitable depth so that they cannot be damaged by service vehicles or farm equipment.
d. The protection limits should be designed so that any over-voltage transferred to the electrical component will not exceed the limits established by the component insulation levels.
e. The ratings of the collector system cable, namely the cables connecting the wind turbine generator to the point of connection, should be verified.
f. Earthing arrangements and protective conductors' selection should be performed according to the IEC 60364-5-54.

5.4.7 Labelling and identification

Inspection of the Wind Turbine Systems should include, at least, the followings check:

a. all circuits, protective devices, switches and terminals are properly labelled according to the requirements of IEC 60364 and IEC 62271 (if the Wind Turbine System is equipped by inverters).
b. means of isolation on the AC side is clearly labelled.
c. a single line wiring diagram is displayed on site.
d. installation details are displayed on site.
e. shutdown procedures are displayed on site.
f. emergency procedures are displayed on site (where relevant).
g. all signs and labels are properly affixed and durable.

5.4.8 Fire protection verification

Inspection should include the followings minimum set of checks:

a. Wiring systems shall be installed so that the general building structural performance and fire safety are not reduced.
b. Cables complying with, at least, the requirements of IEC 60332-1-2 and products classified as non-flame propagating may be installed without special precautions.
c. Cables not complying, as a minimum, with the resistance to the flame propagation requirements of IEC 60332-1-2, if used, should be limited to short lengths for connecting appliances to permanent wiring systems, and, in any cases, their route should not cross two or more different fire segregated compartments.
d. Products, equipment and components classified as non-flame propagating as specified in IEC 60439-2, IEC 61537 and in the following series: IEC 61084, IEC 61386 and IEC 61534, or other applicable international technical standards defining similar requirements, may be installed without particular precautions.
e. Parts of wiring systems, other than cables, which are not classified as non-flame propagating (as specified in IEC 60439-2, IEC 60570, IEC 61537 and in the following series: IEC 61084, IEC 61386 and IEC 61534) but which comply with all the other requirements defined by the applicable product standards should, if used, be completely and reliably enclosed in proper non-combustible building materials.

f. In the event of crossing or proximity of underground telecommunication cables and underground power cables, a minimum clearance distance of 100 mm should be assured and maintained according to the applicable standards.
g. a fire-retardant partition should be provided in between the cables, e.g. bricks, cable protecting caps (clay, concrete), shaped blocks (concrete), protective cable conduit. For cables crossings, mechanical protection between the cables should be provided, e.g. cable conduit, concrete cable protecting caps or shaped blocks.

5.5 Inspection for Wind Turbine systems of Installed Capacity > 2 MVA but less than 25 MVA

5.5.1 General Verifications

a) compliance verification of labels (e.g. cables, terminal blocks, and connectors), drawings and design documents. Check if the cables are tightened in their respective terminals before performing this inspection. Check the wiring execution by performing the following minimum set of verifications:
    a. Labelling of trays and cables according to cable lists (sample check)
    b. LV and MV switchgears: check termination of LV and MV cables and verification that all cables are tightened into their respective clamp terminals
    c. LV and MV switchgears: quantity and characteristics of breakers, disconnect switches and protections. Check their functionality
    d. Inverter connected according to design
    e. Systems for air conditioning and/or ventilation according to design
    f. Connection of switchgears according to design
    g. Connection of LV/MV transformers according to design
b) Quality of cabling:
    a. Tightening of cable glands
    b. Correct installation of DC and AC cables (clamps, sharp edges, folds too narrow, etc.).
    c. Assembly and crimping of plug-in connectors

5.5.2 Verification of the protection against electric shock

Protective barriers or enclosures should prevent, in the case of MV installations and equipment, entering the danger zone by providing a degree of protection of at least IPXXB or IP2X of IEC 60529, and proper measures should be adopted in order to provide a degree of protection of at least IPXXD or IP4X for readily accessible horizontal top surfaces of protective barriers or enclosures.

In MV electrical systems, the expected touch voltages may reach values requiring supply interruption within much shorter times than the quickest opening time of the breakers. One possible solution for the protection of the persons is to create equipotential systems by means of bonding conductors interconnecting all the metallic parts of the installation such as enclosures of switchgears, frames of electrical machines, steel structures, metallic floor pipes, etc. This measure could allow maintaining the touch voltages below the dangerous limit.

5.5.3 Verification of earthing and bonding arrangements

It should be verified the installation of the earthing connection of MV cable shields and the installation or revision of the Lightning protection system (LPS) according to a detailed design.

5.5.4 Verification of the protection against the effects of lightning and overvoltage

It should be verified that the MV switchgear associated with the Wind Turbines has proper protections against lightning and over voltages. The lightning protection zone shall be selected in accordance with IEC 62305.

5.5.5 Verification of the selection and erection of electrical equipment

Unless otherwise specified by the purchaser, the connection group for a two winding three Phase transformer shall be Dyn11 or LV lagging HV by 330 degrees. The adoption of other windings combinations should be discussed and agreed with the manufacturer in accordance with IEC 60076-16

5.6 Inspection for Wind Turbine systems of Installed Capacity >2 MW

5.7 Basic Tests for Wind Turbine Systems

5.7.1 Foreword

Basic Tests represent the minimum test sequence that should be expected on all Small-Scale and Medium Scale Wind Turbine Systems. For inverter-based connections, some of the DC functional tests aimed at assessing the correct inverter operation should be performed according to the applicable technical standards as per requirement and discretion of the inspection office. The aim of the visual inspection, continuity and insulation resistance tests is to verify that field-installed power and control wiring has been developed in compliance with drawings and manufacturer requirements.

In order to perform the compliance verification of Wind Turbine Generating Units with a Registered Capacity of 2MVA or greater, the DSP has the right to carry out, or to witness some testing. In this case, the DSP will indicate, in a timely manner, the required tests, and/or the tests that should be witnessed by the DSP staff or appointed experts. Furthermore, pre-commissioning tests of various MV switchgear equipment such as Wind Turbine transformer, Collector system cables, and breaker systems, should be carried out according to the standard test procedures in the presence of the Inspection office, if it is required or necessitated by the Inspection officer. The corresponding test reports should be made available to the Inspection officer during site visit prior to the Wind Turbine System commissioning.

The following are the minimal tests that should be performed:

5.7.2 Insulation Resistance for Wind Turbine Systems connected to LV network

The insulation resistance test of the AC circuit should be performed according to the requirements of the IEC 60364-6. For LV network this test is performed by applying between live conductors and earth (structures) a test voltage of 1000 VDC for 1 minute. The limit value for acceptance of the measured insulation resistance is 1 MΩ, which should be measured between:

a) live conductors, and
b) live conductors and the protective conductor connected to the earthing arrangement.

Where appropriate during this measurement, live conductors may be connected together. In practice, it may be necessary to perform this measurement during erection of the system before the connection of

the equipment. Where surge protective devices (SPDs) or other equipment are likely to influence the verification test, or be damaged, such equipment shall be disconnected before carrying out the insulation resistance test. Where it is not reasonably practicable to disconnect such equipment (e.g. in case of fixed socket-outlets incorporating an SPD) the test voltage for a particular circuit may be reduced to 250 V DC but the insulation resistance shall have a value of at least 1 MΩ.
To facilitate measurement, the neutral conductor shall be disconnected from the main earthing terminal (MET). In TN-C systems, a measurement should be made between the live conductors and the PEN conductor.

Table 1- Minimum Values of insulation resistance

Nominal Circuit Voltage [V]	Test voltage [V]	Minimum insulation resistance [MΩ]
SELV and PELV	250	0.5
Up to and including, including FELV	500	1
Above 500V	1 000	1

Table 1 should be applied for a verification of the insulation resistance between nonearthed protective conductors and earth.

5.7.3 Continuity test of protective earthing and equipotential bonding conductors

Where protective earthing and/or equipotential bonding conductors are fitted on different switchgear such as wind turbine transformer, protection switchgear (breaker systems and measurement equipment) an electrical continuity test shall be made on all such conductors. The connection to the main earthing terminal should also be verified.

5.7.3.1 Interface Protection

The electrical protection required to ensure that any Generating Unit is disconnected for any event that could impair the integrity or degrade the safety of the Distribution System
Any electrical system that by itself can self-excite the SWT shall be automatically disconnected from the network and remain safely disconnected in the event of loss of network power. If a capacitor bank is connected in parallel with a network connected SWT (i.e. for power factor correction), a suitable switch is required to disconnect the capacitor bank whenever there is a loss of network power, to avoid self-excitation of the SWT electric generator. Alternatively, if capacitors are fitted, it shall be sufficient to show that the capacitors cannot cause self-excitation. Provisions shall be made in order to bleed the capacitors in the event that the capacitor bank cannot be disconnected.

5.7.4 Phase Sequence Test

Before synchronization of 3-Phase Wind Turbine supply terminals, a phase sequence test is conducted to check the uniformity of phase sequence throughout the collector system so as to match with phase sequence of PCC. It shall be verified that the phase sequence is maintained in accordance with IEC 61557-7 standards. The phase sequence indicator shall display a valid phase sequence indication, positive or negative, if the values of the voltage to earth of the three phases are within the voltage range specified above and the phase delay between two consecutive phases is 120°.

The measuring equipment for the phase sequence test with tripolar connection is connected to the three-phase distribution system using three separate test probes marked L1, L2 and L3. Each test probe is connected to the conductor or terminal foreseen to be at the corresponding phase L1, L2 or L3 of the distribution system

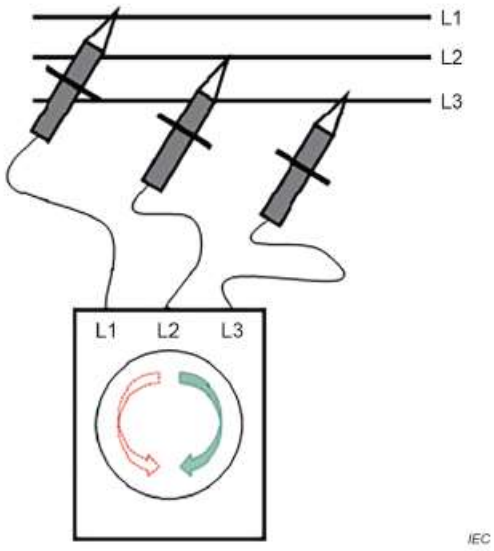

Figure 3 – Phase Sequence Indicator

The phase sequence indication is positive, commonly called "clockwise" (CW) or "right" (R), if the three phases are in the foreseen phase sequence. The phase sequence indication is negative, commonly called "counter-clockwise" (CCW) or "left" (L), if the three phases are in a sequence different than foreseen: two of the three phase connections are crossed

5.7.5 Grounding Grid Resistance Test (Applicable for MV network connected Wind Turbine Systems or Pnom >2 MW)

Earth resistivity measurements are used to perform the following:

a) Estimate the ground impedance of a grounding system
b) Estimate potential gradients including step and touch voltages
c) Compute the inductive coupling between neighboring power and communication circuits
d) Design cathodic protection systems
e) Design alternating current (ac) mitigation for coupling between transmission lines and pipelines
f) Conduct geological surveys

IEEE 81 addresses the common practices for field testing the ground resistance. The most common form of Ground Resistance Testing for Wind Turbines is the Three-Point Fall-of-Potential Method. The measured in ohms value shall be checked with the pre-requisites of energization of Wind Turbine and accordingly remedial measures will be suggested in case the observed resistance values are more than the limits for energization of wind turbines into the grid.

The grid resistance test shall also be conducted to MV switchgear associated with the balance of plant to ensure the effectiveness of grounding systems in absorbing the fault currents and safety for working personnel.

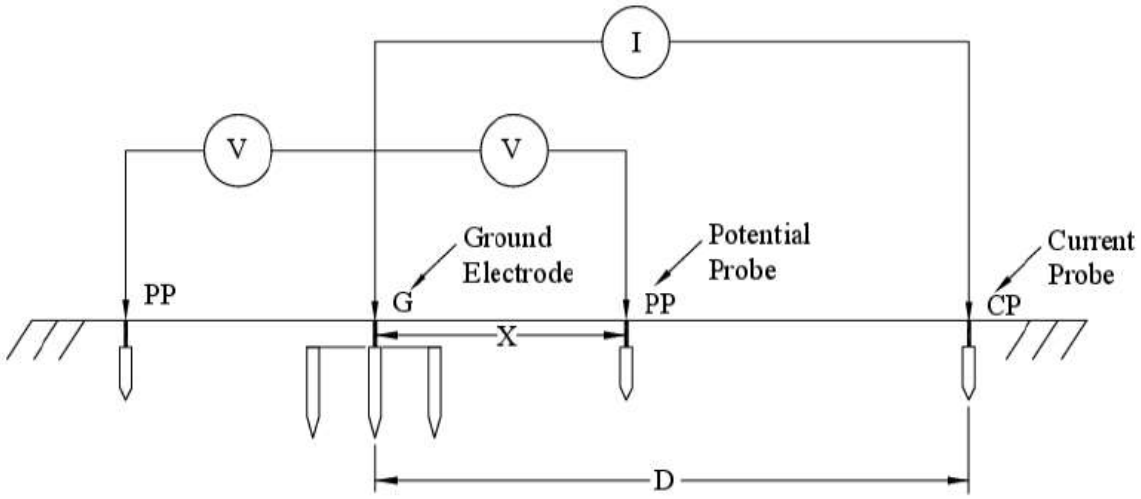

Figure 4 – Illustrative diagram of 3-point Fall of Potential Method

5.8 Additional tests

5.8.1 Foreword

Additional tests are normally intended for larger or more complex systems. All Basic tests shall have been undertaken and passed before commencing on the Additional tests.
In addition to the Basic tests, the following Additional tests may be applied:

a) Functional Tests-
b) Interface Protection Test –
c) Monitoring, remote control and information exchange
d) Additional tests on Wind Turbine Transformers.
e) Active Power Control

Furthermore, the wind turbine system equipped with type-tested wind turbines should comply with the grid code requirements. However, SEC reserves the right to verify the type-test reports in order to ensure the compliance with the connection and operation requirements. Also, SEC reserves the right to re-perform some of the tests to check the compliance with grid codes. The below additional tests shall be performed based on the requirement and type or capacity of the wind turbine system under study.

Moreover, if required or necessitated by the Inspection officer, pre-commissioning tests of various MV switchgear equipment, such as Wind Turbine transformer, Collector system cables, and breaker systems, should be carried out according to the standard testing procedures in the presence of the Inspection officer. The corresponding test reports of such equipment should be made available to the Inspection officer during site visit prior the Wind Turbine System commissioning.

5.8.2 Functional Tests-

Equipment should be subjected to functional testing in order to verify that it is properly mounted, adjusted and installed in accordance with the relevant requirements of the IEC 60364 series. Examples of such equipment are:

- switchgear and control gear assemblies, drives, controls and interlocks,

- systems for emergency switching off and emergency stopping,
- insulation monitoring.

Protective devices should be accurately tested in order to check that they are properly installed, tuned and coordinated. Where fault protection and/or additional protection is provided by an RCD, the effectiveness of any test facility incorporated in the device should be verified.
All the basic operations of the MV switchgear should be tested at the site in accordance with IEC 62271 and other applicable standards.

5.8.3 Interface Protection Test

Wind Turbine System operating in parallel with the power distribution network should be equipped with the following protective functions aimed at sensing abnormal conditions of the electrical grid and automatically disconnecting the Wind Turbine System in order to safeguard the distribution network (e.g. avoiding electrical islanding).:

a) the Distribution Network (or the feeder) connecting the Wind Turbine System is de-energized from the main supply source. De-energization can happen automatically due to protection system operation or manual/electrical disconnection. Electrical/manual disconnection in the Distribution Network can happen either remotely by SEC SCADA system or by local switching.
b) Over and under voltage trip functions if voltage at the point of connection reaches the limits as specified in *Technical Standards for the Connection of wind turbine systems to the LV and MV Distribution Networks of SEC*
c) Over and under frequency trip functions, if frequency at point of connection reaches limits as specified in *Technical Standards for the Connection of wind turbine systems to the LV and MV Distribution Networks of SEC*
d) A function that allows the Wind Turbine System to promptly interrupt energizing the circuit to which it is connected in the presence of any fault in the circuit.
e) A voltage and frequency sensing and time-delay function aimed at *(i)* preventing the Wind Turbine System to energize a de-energized circuit, and *(ii)* reconnecting the wind turbine system to an energized circuit only if the voltage and frequency are within the prescribed limits, and are stable for at least sixty seconds.
f) A function to prevent the Wind Turbine System to contribute to the formation of an unintended electrical island, by interrupting energizing the electricity system within two seconds after the formation of an unintended Island.

A wind turbine system that was disconnected by an external signal prior to a fault occurring in the distribution network must not be reconnected until the external signal has been eliminated, and the voltage and frequency are within their normal operating conditions and are stable for at least sixty seconds. Only the approved protection settings from SEC should be adopted and the functionalities of the protection relays/equipment should be verified as per the requirements stated in the above points.

The minimal tests that should be carried out on the over voltage and under voltage protection for each phase include the followings verifications:

a) The operating voltage shall be checked by applying nominal voltage to the protection (so that it resets) and then slowly increasing this voltage (for over voltage protection) or reducing it (for under voltage protection) until the protection picks up. The voltage at which the protection picks up shall be recorded. Where the test equipment increases/decreases the voltage in distinct steps, these shall be no greater than 0.5% of the voltage setting. Each pickup value shall be within 1.5% of the required setting value.

b) Timing tests shall be carried out by stepping the voltage from the nominal voltage to a value 4V above the setting voltage (for overvoltage protection) and 4V below the setting (for under voltage protection) and recording the operating time of the protection. The operating time of the protection shall be no shorter than the setting and no greater than the setting required.

In the similar way the over frequency and underfrequency tripping characteristics of the protection relays at the point of connection shall be tested by applying nominal frequency to the protection (so that it resets) and then slowly increasing this frequency (for over frequency protection) or reducing it (for under frequency protection) until the protection picks up. The frequency at which the protection picks up shall be recorded. Where the test equipment increases / decreases the frequency in distinct steps, these shall be no greater than 0.1% of the frequency setting. Each pick up value shall be within 0.2% (i.e. 0.1Hz) of the setting value. (The limits can be altered by SEC as per requirements)

Timing tests shall be carried out by stepping the frequency from 0.3Hz below the setting frequency to a value 0.3Hz above the setting frequency (for over frequency protection) and 0.3Hz above the setting (for under frequency protection) and recording the operating time of the protection. The operating time of the protection shall be no shorter than the setting and no greater than the setting + 100ms (can be altered by DSO if required) or the setting + 1% of the setting, whichever gives the longer time.

5.8.4 Monitoring, remote control and information exchange

Adequate information concerning the Consumers connected to the Distribution Networks is a prerequisite for enabling SEC to maintain the stability, reliability and security of its networks. SEC needs to have a continuous overview of the state of the network, which may require, in some cases, updated information on the operating conditions of the Wind Turbine Systems connected to its Distribution Networks, as well as the possibility to communicate with these plants in order to direct the operational instructions set forth by the provisions as per *Technical standards for connection of wind turbine systems.* Demonstration of signal interface with the remote system/ SCADA system of SEC shall be made to check the compliance with this requirement.

5.8.4.1 For Wind Turbine System 2 MVA:

Wind turbine systems must be designed in order to receive an external start signal ('released for start') and an external stop signal. The external signals are expected to be pulse signals.

Table 2 - Requirements for information which a power-generating plant below 2 MW must be capable of exchanging.

Signal Type	Signal Description
Command	Stop signal
Command	Holding signal – 'Released for start'

A power-generating plant may start production when the reconnection criteria are met, and the 'Released for start' signal has been received. Exchange of information can be performed via a terminal block or via an RTU, subject to agreement with SEC.

5.8.4.2 For Wind Turbine System less than 2 MVA:

Wind turbine systems belonging to this category must be able to exchange the following minimum set of signals in accordance with the specifications as per *Technical standards for connection of wind turbine systems and IEC 61400-25 series.*

Table 3 - Requirements for information which a power-generating plant less than 2 MW must be capable of exchanging.

Signal Type	Signal Description
Status	Switch gear status in the *plant's Point of Connection*
Measurement	Active power kW – measured in the *Point of Connection*
Status	Active power kW – set point for active power
Measurement	Reactive power MVAr – measured in the *Point of Connection*
Command	Stop signal
Command	Holding signal – 'Released for start'

5.8.4.3 For Wind Turbine System with Pnom > 2 MW:

Wind turbine systems belonging to this category must be able to exchange the following minimum set of signals in accordance with the specifications as per *Technical standards for connection of wind turbine systems and IEC 61400-25 series.*

Table 4 - Requirements for information which a power-generating plant above 2 MW must be capable of exchanging

Signal Type	Signal Description
Status	Switch gear status in the *plant's Point of Connection*
Measurement	Active power kW – measured in the *Point of Connection*
Status	Active power kW – set point for active power
Set Point	Active power control – *ramp rate constraint*
Set Point	Active power control – ramp rate for upward regulation of active power
Set Point	Active power control – ramp rate for downward regulation of active power
Set Point	Active power control – *absolute power constraint*
Set Point	Active power control – desired maximum active power
Set Point	Active power control – *delta power constraint*
Set Point	Active power control – desired regulating reserve – P_{delta}
Measurement	*Power factor* – calculated on the basis of measurements in the *Point of Connection*
Set Point	*Power factor* set point – desired *Power Factor* in the *Point of Connection*
Enabled/disabled	Reactive power control – activated/deactivated
Set Point	Reactive power control – desired reactive power in the *Point of Connection*
Measurement	Voltage – voltage measured in the *voltage reference point*
Status	Circuit Breaker at the PCC
Enabled/disabled Status	Overspeed protection – activated/deactivated
Measurement	Reactive power MVAr – measured in the *Point of Connection*
Command	Stop signal
Command	Holding signal – 'Released for start'

It should be noted that some of these signals may not be applicable according to the Wind Turbine system design specifications.

A wind turbine system must be equipped with an information exchange system in order to be able to stop the active power generation. Generation must be stopped no later than five seconds after the stop command has been received.
In general, Wind Turbine System should comply with the following minimal set of control and performance interface requirements in order to allow the remote control and the information exchange with SEC, and with the remote-control systems:

a) capability to receive dispatch instructions through an automatic remote control or SCADA system, (i) to switch in or out frequency sensitive mode based upon Active Power Delta Regulation, (ii) to adopt a set point of Active Power output, (iii) to set an Absolute Active Power Limitation and (iv) to switch in or out and control ramp rate by setting an Active Power Gradient;
b) automatic confirmation, enactment of Dispatch Instructions received and confirmation that the instructed action has been achieved.
c) as far as the accuracy of the set point adjustment and the resulting control action are concerned, there shall not be any deviation of more than 2% of the set point value, or by 0.5% of the rated power, whichever provides the closer tolerance and the action shall be completed in less than 10 minutes after receipt of the Dispatch Instruction. In making such assessment due regard shall be taken of the available wind turbine system and the power curve as specified/set out in the Connection Agreement.

The information exchange with the SEC should be checked as per the above-mentioned requirements. Further functionality of commands shall be tested from the SEC remote control centre.

5.8.5 Additional tests on Wind Turbine Transformers

Due to the harsh operating environment for wind turbine transformers, a number of tests in addition to the standard tests applied shall be carried out as per IEC 60076-16, *transformers for wind turbine applications*.

Where specified by the purchaser, a partial discharge test in accordance with the method specified in IEC 60076-11 or IEEE Std C57.12.01 shall be carried out. The maximum acceptable level of partial discharge shall be 100 pC.

5.8.6 Active Power Control

A wind turbine system must be equipped with system protection – a control function that must be capable of quickly regulating the active power supplied by the wind turbines to one or more predefined set points based on a downward regulation order. Set points are determined by the electricity supply undertaking upon commissioning within the framework laid down by the transmission system operator. Such requirements should be demonstrated through tests that the plant is capable of meeting the function requirements by the plant owner.

6 COMMISSIONING TEST

The Commissioning Test shall be performed on all the Wind Turbine systems, regardless their power capacity. However different requirements apply to the Wind Turbine systems with reference to their power capacity.
The Commissioning Test includes the verifications listed below.

- Interface Protection.
- Measurement of Harmonics, Flicker

- Performance monitoring functions.
- Evaluation of the Power Performance of Wind Turbine as per IEC 61400-12
- Post Connection Inspection

6.1 Interface Protection

After the Wind Turbine system has been connected to the distribution grid and powered, the following verifications should be performed:

- The Interface Protection settings (functions, thresholds and times) are those required by SEC in accordance with the parameters defined in the Technical Standards
- The Interface device disconnects the Wind Turbine system in the presence of power failure on command of the Interface Protection
- After a power recovery the Interface Protection recloses the Interface device.

In addition, the commissioning test should ensure that following verifications are performed as a minimum, before commissioning:

i. Test Run: To witness and evaluate the 96 hrs test run of the newly installed wind turbines.
ii. All unforeseen stoppages and Grid failures during the test run will be noted.
iii. The demonstration of functionality of various control and protection system of the selected wind turbine will be witnessed and noted.
iv. The mandatory pre-commissioning test/procedures of the ancillary infrastructure such as electrical protection system, switchgears, transformer, etc.,

6.2 Measurement of Harmonics & Flicker

Measurement of harmonic current injection, Direct Current injection and flicker shall be done with calibrated meters before the project commissioning and once in a year in presence of the parties concerned and the indicative date for the same shall be mentioned in the connection agreement.
Provided that in addition to annual measurement, if appropriate licensee or the generating company, as the case may be, desires to measure harmonic current injection or Direct Current injection or flicker, it shall inform the other party in writing and the measurement shall be carried out within ten working days.

6.2.1 Power Quality Measurement

The measurement procedures are valid for single wind turbines with a three-phase grid connection. The measurement procedures are valid for any size of wind turbine, though IEC 61400-21 only requires wind turbine types intended for connection to an electricity supply network to be tested and characterized as specified in IEC 61400-21. The wind turbine should be connected directly to the network through a standard transformer (i.e. equal or electrically comparable to a transformer to be used in other applications than the prototype measurement) with nominal apparent power at least corresponding to the nominal apparent power of the assessed wind turbine. The total harmonic distortion of the voltage including all harmonics up to the order of 50 shall be less than 5 % measured as 10 min average data at the wind turbine terminals while the wind turbine is not generating. The total harmonic distortion of the voltage may be determined by measurement prior to testing the wind turbine.

6.2.2 Flicker Measurement

For wind turbines, flicker testing should be carried out during the performance tests specified in IEC 61400-12. Flicker data should be recorded from wind speeds of 1ms-1 below cut-in to 1.5 times 85% of the rated power. The wind speed range should be divided into contiguous bins of 1ms-1 centered on multiples of 1ms-1. The dataset shall be considered complete when each bin includes a minimum of 10 minutes of sampled data.

The highest recorded values across the whole range of measurements should be used as inputs to the calculations described in IEC 61000 to remove background flicker values. Then the required maximum supply impedance values can be calculated. Note that occasional very high values may be due to faults on the associated HV network and may be discounted, though care should be taken to avoid discounting values which appear regularly

6.3 Performance monitoring functions

Power curve of a wind turbine depicts the relationship between output power and hub height wind speed, and it is an important characteristic of the turbine. Power curve aids in energy assessment, warranty formulations, and performance monitoring of the turbines. The power curve is one of the most important characteristics of a wind turbine generator. For manufacturers, a measurement report that shows strong performance can be a powerful sales tool. For operators and investors, the power curve of a generator is a key parameter of the economic value of a wind project. In both cases it is highly recommended to have the measurement performed according to recognized standards.

The IEC 61400-12 specifies a procedure for measuring the power performance characteristics of a single wind turbine and applies to the testing of wind turbines of all types and sizes connected to the electrical power network. In addition, this standard describes a procedure to be used to determine the power performance characteristics of small wind turbines (as defined in IEC 61400-2) when connected to either the electric power network or a battery bank. The procedure can be used for performance evaluation of specific turbines at specific locations, but equally the methodology can be used to make generic comparisons between different turbine models or different turbine settings. The wind turbine power performance characteristics are determined by the measured power curve and the estimated annual energy production (AEP). The measured power curve is determined by collecting simultaneous measurements of wind speed and power output at the test site for a period that is long enough to establish a statistically significant database over a range of wind speeds and under varying wind and atmospheric conditions. The AEP is calculated by applying the measured power curve to reference wind speed frequency distributions, assuming 100 % availability.

The standard describes a measurement methodology that requires the measured power curve and derived energy production figures to be supplemented by an assessment of uncertainty sources and their combined effects.
At the test site a meteorological mast shall be set up in the neighborhood of the wind turbine to determine the wind speed that drives the wind turbine. The test site may have significant influence on the measured power performance of the wind turbine. In particular, flow distortion effects may cause the wind speed at the meteorological mast and at the wind turbine to be different, though correlated.
The test site shall be assessed for sources of wind flow distortion in order to

– choose the position of the meteorological mast.
– define a suitable measurement sector.
– estimate appropriate flow correction factors.
– evaluate the uncertainty due to wind flow distortion.

The following factors shall be considered, in particular:

– topographical variations.
– other wind turbines.
– obstacles (buildings, trees, etc.)

Care shall be taken in locating the meteorological mast. It shall not be located too close to the wind turbine, since the wind speed will be influenced/changed/affected in front of the wind turbine. Also, it shall not be located too far from the wind turbine, since the correlation between wind speed and electric power output will be reduced. The meteorological mast shall be positioned at a distance from the wind turbine of between 2 and 4 times the rotor diameter D of the wind turbine. A distance of 2,5 times the rotor diameter D is recommended.

The net electric power of the wind turbine shall be measured using a power measurement device (e.g. power transducer) and be based on measurements of current and voltage on each phase.
The class of the current transformers shall meet the requirements of IEC 60044-1 and the class of the voltage transformers, if used, shall meet the requirements of IEC 60186. They shall be class 0,5 or better. The accuracy of the power measurement device, if it is a power transducer, shall meet the requirements of IEC 60688 and shall be class 0,5 or better. If the power measurement device is not a power transducer then the accuracy should be equivalent to class 0,5 power transducers. The operating range of the power measurement device shall be set to measure all positive and negative instantaneous power peaks generated by the wind turbine. As a guide, the full-scale range of the power measurement device should be set to −50 % to +200 % of the wind turbine rated power. All data shall be periodically reviewed during the test to ensure that the range limits of the power measurement device have not been exceeded.

The power transducer shall be calibrated to traceable standards. The power measurement device shall be mounted between the wind turbine and the electrical connection to ensure that only the net active electric power (i.e. reduced by self-consumption) is measured. It shall be stated whether the measurements are made on the turbine side or the network side of the transformer.

6.3.1 Data acquisition, timing and reporting

Data shall be collected continuously at a sampling rate of 1 Hz or higher. Air temperature, air pressure and humidity and precipitation, if measured, may be sampled at a slower rate, but at least once per minute.
The data acquisition system shall store either sampled data or statistics of data sets as follows:

a) mean value.
b) standard deviation.
c) maximum value.
d) minimum value.

Selected data sets shall be based on 10-min periods derived from contiguous measured data. Data shall be collected until the requirements defined in 8.5 of IEC 61400-12 are satisfied.

After data normalization the selected data sets shall be sorted using the “method of bins” procedure. The wind speed range shall be divided into 0,5 m/s contiguous bins centered on multiples of 0,5 m/s. The selected data sets shall at least cover a wind speed range extending from 1 m/s below cut-in to 1,5 times the wind speed at 85 % of the rated power of the wind turbine. Alternatively, the wind speed range shall extend from 1 m/s below cut-in to a wind speed at which "AEP-measured" is greater than or equal to 95 % of "AEP extrapolated", where “AEP-measured” and “AEP-extrapolated” are defined using the appropriate, consistent definitions of wind speed (i.e. the hub height wind speed derived, power curve and wind speed distribution and, in the case where REWS is derived, by the REWS derived power curve and wind speed distribution).

For active pitch controlled wind turbines, the power curve may also be considered complete when the rated power has been reached and the average power does not change by more than the larger of 0,5

% of the power or 5 kW for three consecutive wind speed bins and there is not a trend of increasing power across these three bin-averages. The report shall state which of the three wind speed range criteria has been used.
The database shall be considered complete when it has met the following criteria:

a) each bin includes a minimum of 30 min of sampled data.
b) the database includes a minimum of 180 h of sampled data.

Should a single incomplete bin be preventing completion of the test, then that bin value can be estimated by linear interpolation from the two adjacent complete bins.

6.3.2 Calibration and inspection

Wind speed measurements shall be made with a cup anemometer that meets the requirements in Annex I of IEC 61400-12. For power performance measurements an anemometer is a class better than 1,7A or 1,7C shall be used. Additionally, in terrain that requires a site calibration, it is recommended that a class better than class 2,5B, 2,5D or 1,7S shall be used. The anemometer shall be calibrated before and, if required, calibrated again after the measurement campaign (post-calibration). It is mandatory to check and document that the anemometer maintains the validity of its calibration throughout the measurement period. This can be achieved by either comparing the initial calibration results with the outcome of the post-calibration or as an alternative, the in-situ anemometer comparison following Annex K of IEC 61400-12 is permissible.

Remote sensing devices that assume horizontal flow uniformity through the scanned volume limit the application of these technologies to non-complex terrain conditions for power performance testing. The remote sensing device shall be verified before the measurement campaign or in-situ. The remote sensing device can be used to measure hub height wind speed, wind shear profile, wind veer and/or the rotor equivalent wind speed based on measurements at more than one height.

In any case, the remote sensing device shall be simultaneously compared with a top-mounted anemometer on a meteorological mast at a height not less than the minimum of the wind turbine rotor lower tip-height or 40 m. Wind direction should be measured with a wind vane. A wind vane used for this purpose shall be mounted on the meteorological mast on a boom, as described in Annex G. The combined calibration, operation, and orientation uncertainty of the wind direction measurement should be less than 5º.

Air density: The air density may be determined from measured air temperature and air pressure according to the equation

$$\rho_{10\min} = \frac{B_{10\min}}{R_0 \cdot T_{10\min}}$$

Where,

$\rho_{10\min}$ is the derived 10 min averaged air density.
$T_{10\min}$ *is* the measured absolute air temperature averaged over 10 min.
$B_{10\min}$ is the measured air pressure averaged over 10 min.
Ro is the gas constant of dry air 287,05 J/ (kg × K).

For a stall-regulated wind turbine with constant pitch and constant rotational speed, data normalization shall be applied to the measured power output according to the equation:

Air density shall be derived from the measurement of air temperature and air pressure using equation. At high temperatures, it is recommended also that relative humidity be measured and corrected for. The correction for the density effect of the air humidity shall be performed using equation in IEC 61400-12 The air temperature sensor, and the humidity sensor if used, shall be mounted within 10 m of hub height to represent the air temperature at the wind turbine rotor center.

The air pressure sensor should be mounted on the meteorological mast close to hub height to represent the air pressure at the wind turbine rotor center. If the air pressure sensor is not mounted close to the hub height, air pressure measurements shall be corrected to the hub height according to ISO 2533.

Rotational speed and pitch angle:
Rotational speed and pitch angle should be measured throughout the test if there is a specific need for it, for example if there is a need to apply the measurements in connection with acoustic noise tests. If measured, the measurements shall be reported according to IEC 61400-12-1.

Blade condition
The condition of the blades may influence the power curve particularly for stall regulated turbines. It may be useful in understanding the characteristics of the turbine to monitor the factors which might affect blade condition. These include precipitation, icing and bug and dirt accretion.

Wind turbine control system
Sufficient status signals shall be identified, verified and monitored to allow the rejection criteria to be applied. Obtaining these parameters from the turbine controller's data system, if available. The definition of each status signal shall be reported.

6.3.3 Measured parameters

The following are the typical signals that shall be measured are (according to IEC 61400-12-1):

a) wind speed on the meteorological mast.
b) wind direction on the meteorological mast.
c) wind turbine power.
d) air temperature.
e) air pressure.
f) turbine generator grid connection status signal.

In addition to the requirements of the IEC 61400-12-1:2005, the following signals shall be measured:

a) nacelle wind speed.
b) nacelle wind direction.
c) nacelle yaw position.

The following signals may be captured, to establish validity of the measured transfer function for future use:

a) rotor speed.
b) pitch angle(s).

The net electric power of the wind turbine shall be measured using a power measurement device (e.g. power transducer) and be based on measurements of current and voltage on each phase. The class of the current transformers shall meet the requirements of IEC 60044-1 and the class of the voltage transformers, if used, shall meet the requirements of IEC 60186. They shall be class 0,5 or better. The accuracy of the power measurement device, if it is a power transducer, shall meet the requirements of IEC 60688 and shall be class 0,5 or better. If the power measurement device is not a power transducer

then the accuracy should be equivalent to class 0,5 power transducers. The operating range of the power measurement device shall be set to measure all positive and negative instantaneous power peaks generated by the wind turbine. As a guide, the full-scale range of the power measurement device should be set to −50 % to +200 % of the wind turbine rated power.

6.3.4 Data processing and quality check

To ensure that only data obtained during normal operation of the turbine are used in the analysis, and to ensure data are not corrupted, data sets shall be excluded from the database under the following circumstances:

– external conditions other than wind speed are out of the operating range of the wind Turbine.
– turbine cannot operate because of a turbine fault condition.
– turbine is manually shut down or in a test or maintenance operating mode.
– failure or degradation (e.g. due to icing) of test equipment.
– wind direction outside the measurement sector(s).
– wind directions outside valid (complete) site calibration sectors.

Any other rejection criteria shall be clearly reported.
The power curve shall capture the effect of hysteresis at the cut-in control algorithm, as well as the effect of parasitic losses below cut-in. The effect on the power curve of a large hysteresis loop in the cut-out control algorithm may be considerable. In case cut-out behavior has been reached during the measurement period, two data sets shall therefore be presented. One data set shall include all data points in the database. The other data set shall exclude all data sets where the turbine has stopped generating power due to cut-out at high wind speed. Subsets of the database collected under special operational conditions (e.g. high blade roughness due to dust, salt, insects, ice) or atmospheric conditions (e.g. precipitation, wind shear) that occur during the measurement period may be selected as special databases. If the grid frequency varies on the order of two or more hertz, it might be appropriate to select the power performance at different frequency levels as a special database. In this case, the grid frequencies should be divided into frequency bins, centered on integer values of the grid frequency.

6.3.5 Calculated parameters

The power curve shall be determined based on the hub height wind speed and, if measured, the rotor equivalent wind speed. However, it should be remembered that the uncertainty in a power curve derived from hub height measurements only is subject to higher uncertainty due to the lack of knowledge of other influential wind condition parameters. Therefore, to account for the vertical wind shear, wind veer and turbulence intensity and to reduce power curve measurement uncertainty, it is recommended to consider the rotor equivalent wind speed as the representative wind speed and the turbulence normalized power output as the relevant power output. The derivation of power curves based on wind speed normalized for a specific wind shear and the turbulence normalized power output are options that are recommended if a comparison between different power curves is wanted or if the power curves are applied for wind resource assessment.

To indicate single 10-min averages, a further index j should be added to the respective wind speeds.
The measured power curve is determined by applying the "method of bins" for the normalized data sets, using 0,5 m/s wind speed bins and by calculation of the mean values of the normalized wind speed and normalized power output for each wind speed bin according to Equations given below:

$$V_i = \frac{1}{N_i} \sum_{j=1}^{N_i} V_{n,i,j}$$

$$P_i = \frac{1}{N_i} \sum_{j=1}^{N_i} P_{n,i,j}$$

where

Vi is the normalized and averaged wind speed in bin i.
Vn, i, j is the normalized wind speed of data set j in bin i.
Pi is the normalized and averaged power output in bin i.
Pn, i, j is the normalized power output of data set j in bin i.
Ni is the number of 10 min data sets in bin i.

The AEP shall be calculated in two ways, one designated “AEP-measured”, the other “AEPextrapolated”. If the measured power curve does not include data up to cut-out wind speed, the power curve shall be extrapolated from the maximum complete measured wind speed up to cut-out wind speed. Furthermore, AEP may be defined as generic AEP or site-specific AEP.

Generic AEP is estimated by applying the measured power curve to different reference wind speed frequency distributions. For a specific development, nominal site conditions specifying the wind climate of the site may be known. If so, a site-specific AEP may, additionally, be reported and computed based on this site-specific information. It is emphasized that a power curve derived from hub height wind speed measurements shall only be combined with a wind speed frequency distribution based on the hub height wind speed definition to derive AEP whereas a power curve derived from REWS measurements shall only be combined with a REWS frequency distribution to derive AEP.

The AEP derived from combining a REWS power curve with a hub height wind speed frequency distribution (and vice versa) is not a valid calculation. A Rayleigh distribution, which is identical to a Weibull distribution with a shape factor of 2, shall be used as the reference wind speed frequency distribution. AEP estimations shall be made for hub height annual average wind speeds of 4 m/s, 5 m/s, 6 m/s, 7 m/s, 8 m/s, 9 m/s, 10 m/s and 11 m/s according to equation below:

$$AEP = N_h \sum_{i=1}^{N} [F(V_i) - F(V_{i-1})] \left(\frac{P_{i-1} + P_i}{2} \right)$$

where

AEP is the annual energy production.
Nh is the number of hours in one year ≈ 8 760.
N is the number of bins.
Vi is the normalized and averaged wind speed in bin i.
Pi is the normalized and averaged power output in bin i.

The summation is initiated by setting Vi–1 equal to Vi – 0,5 m/s and Pi–1 equal to 0,0 kW. For a specific site, nominal site conditions specifying the wind climate of the site may be known. If so, a site-specific AEP may, additionally, be reported and computed based on this site-specific information. If the site-specific wind distribution is known and is present in tabular form, the site-specific AEP may be calculated by first transforming the wind distribution to the corresponding cumulative distribution.

The number of hours up to each measured wind speed of the measured power curve will be derived by linear interpolation between two adjacent values of the cumulative distribution. The hours will be divided by the sum of hours in the table, which is typically the nominal number of hours within a calendar year. Finally, the AEP will be calculated by using above equation. The tabular wind speed distribution shall use the same definition of wind speed (hub height or REWS) as the measured power curve otherwise a valid AEP cannot be derived.

Power coefficient:
The power coefficient, CP, of the wind turbine shall be added to the test results and presented as detailed in IEC 61400-12. CP shall be determined from the measured power curve according to below equation:

$$C_{P,i} = \frac{P_i}{\frac{1}{2}\rho_0 A V_i^3}$$

where

CP, i is the power coefficient in bin i.
Vi is the normalized and averaged wind speed in bin i (matching the defined wind speed as either rotor equivalent wind speed or hub height wind speed).
Pi is the normalized and averaged power output in bin i.
A is the swept area of the wind turbine rotor.
ρ0 is the reference air density

6.3.6 Test report

The final test report should include both the Test Procedure (either explicitly or by reference) and should be developed in accordance with IEC 61400-12.

6.4 Post Connection Inspection

The Post-Connection site inspection is aimed at:

- Making the final checks on the installation, if necessary.
- Verifying the proper behaviour of the meters, if necessary.
- Supervising the Power Performance Tests if repeated by the Applicant, on explicit request of SEC, if considered necessary; and
- Obtaining the reading of the meters in order to begin to consider the exports and net metering.

The checks results related to the energy meters shall be reported in the appropriate section of the checklist. The results of the repetition of the Performance Tests could also be reported in the same document, if necessary.
After the grid connection and the powering of the Wind Turbine system, the following minimum verifications should be performed:

- The Interface Protection settings (functions, thresholds and times) are those required by SEC in accordance with the parameters defined in the Technical Standards
- The Interface device disconnects the Wind Turbine system in case of power failure on command of the Interface Protection
- After a power recovery the Interface Protection recloses the Interface device.

ANNEX A – SAFETY INFORMATION FORM

The following form indicating specific risks and on-site safety measures should be filled and delivered by the Applicant / Contractor to SEC or to any other concerned Authority or Inspectors (e.g. Test Engineer) visiting the site of the Wind Turbine System.

Safety Information Form	
Wind Turbine system	
Type of Applicant	☐ Individual ☐ Organization
Organization (if applicable)	
First name	
Last name	
P.O. Box	
Street number	
Street name	
Location / Area	
City	
Voltage delivery	☐ 220 V (3 phases) ☐ 230V (1 phase) ☐ 400 V (3 phases) ☐ 13.8 kV ☐ 33 kV ☐ 69 kV
Wind Turbine capacity individual and Cumulative [kW]	
Wind Turbine System installation	☐ On building ☐ Ground
Wind Tracking System	☐ Tail ☐ Yaw motors ☐ Fixed
Wind Turbine Tower height (hub height)	
No of blades, blade length and swept area	
Notes on safety measures to access the Wind Turbine System.	
Location of equipment	
Wind Turbine Generator	
Generator Transformer	
LV Switchgears	
MV Switchgear	
Collector system's cables/ conductors	
Notes on safety measures to access the equipment	

Safety Information Form	
Interferences with other works	
Location of fire hydrants and fire extinguishers	

Risks in the workplace and related prevention and protection measures

Specific risk	Collective Protection	PPE
Electric shock		
Falls		
Slipping		
Dust		
Harmful substances		
Working at heights		