EP-EPP-S2

Technical Specifications for the Connection of Wind Turbine Systems to the LV and MV Distribution Networks of Kahramaa

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1 Purpose

This document provides a specific set of technical requirements for the connection of Wind Turbine Systems to the LV & MV Distribution Network of Kahramaa.

2 Scope

This document is applicable to Wind Turbine Systems with maximum capacity of 25 MW, which are connected to up to 33 kV grid voltage level. The requirements defined in this document should be fulfilled regardless of the presence of local electrical loads.

The current Technical Specifications for grid-connected Wind Turbine Systems define:

a) Requirements for the equipment used for interconnecting a Wind Turbine System to the distribution network.
b) Requirements for grid services aimed at enhancing the frequency and voltage stability of the power system in the presence of disturbances.
c) Requirements for the start-up, operation and disconnection of the Wind Turbine Systems.
d) Requirements aimed at preventing disturbances and damages induced by the Wind Turbine Systems on the distribution network and other Customers connected to the same distribution network.
e) Requirements aimed at avoiding parallel operation of the Wind Turbine Systems with an island or portion of the distribution network, which has been disconnected on purpose from the main power system.

The present document is not contradicting additional requirements defined by other national & international standards, network codes or specific technical requirements of Kahramaa, and which may apply to the connection of a Wind Turbine System, including, but not limited to the following:

- The Qatar Transmission Grid Code – Issue ES-M4 – Revision 0.0 – March 2020 and amendments in force (hereinafter “Transmission Code”)
- CS-CSI-P1/C1 – Kahramaa’s Low Voltage Electricity Wiring Code 2016
- CS-CSI-P1 E_W – Building Permit Issuance
- Qatar Construction Specifications latest edition

All the Contractors and Consultants should follow the Qatari regulations in their latest edition. Specifically, the Consultants and Contractors shall follow the last edition of the *Qatar Construction Specifications* document for all the non- Wind Turbine components of the Wind Turbine Systems required in the electrical design, installation and connection of a Wind Turbine System.

The above indicated Transmission Code is also applicable to all distribution system users. The present document should be applied for a new or modified plant installation, which includes a Wind Turbine System, and the defined requirements should be considered as an extension of the Transmission Code for what is not directly ruled by the code itself. For all the aspects not directly covered by the present document, reference shall be made to the Kahramaa Transmission Code. This information can be found in other companion documents, as listed in section 2.

Finally, it is not under the purpose of this document to define technical rules for the off-grid networks operation in isolated (e.g., rural) areas, where no part of Kahramaa distribution network is involved.

Unless otherwise explicitly specified, the requirements set forth by the present Technical Specifications apply to new Wind Turbine Systems, i.e., to those Wind Turbine Systems which do have not already been approved by Kahramaa at the date of publication of this Technical Specifications.

2.1 Notice to Users of these Guidelines

This document is for the use of employees of Kahramaa, Customers, Consultants, Contractors, and Manufacturers. Users of this document should be aware of the applicable laws and regulations. Users are responsible for observing or referring to the applicable regulatory requirements. Kahramaa, by the publication of this document, does not intend to urge action that is not in compliance with applicable laws, and these documents may not be construed as doing so.

Users should be aware that this document may be superseded at any time by the issuance of new editions or may be amended from time to time through the issuance of amendments, corrigenda, or errata. At any point in time, these Technical Specifications consist of the current edition of the document together with any amendments, corrigenda, or errata in effect. All users should ensure that they have the latest edition of this document uploaded on Kahramaa website.

Finally, unless otherwise specified, the User shall refer to all applicable Kahramaa Standards, Qatar Standards, or International Standards mentioned in this document.

DISCLAIMER

These Technical Specifications are provided without a consolidated Framework Regulation by Kahramaa; therefore, the content of the present document may be subject to change in the next revisions of the document.

2.2 Kahramaa Limitation of Liability and Customer's undertaking

Kahramaa disclaims liability for any personal injury, property or other damage of any nature whatsoever, whether special, indirect, consequential, or compensatory, directly or indirectly resulting from the connection point. Customers are responsible for observing or referring to the applicable laws and regulatory requirements.

It is the Customer's responsibility through their Consultant/Contractor to determine the interconnection equipment's specifications and confirmed performance to satisfy the technical needs of the Kahramaa network and be compatible with the present and any other applicable Kahramaa standards. All equipment in an installation connected to Kahramaa network shall be designed, manufactured, tested and installed following all applicable statutory obligations and shall conform to the relevant Kahramaa standards current at the time of the connection of the installation to Kahramaa network.

The Customer shall undertake to comply with the following:

a) Arrange all necessary components satisfying the technical requirements for reliable connection of the Wind Turbine System to Kahramaa network, including compliance with security and safety requirements in providing all the equipment.
b) Comply with the terms and conditions for the Wind Turbine System connection, such as the *Connection Agreement*, connection conditions, and any other relevant requirement adopted by Kahramaa.
c) Do not exceed the authorised Maximum Connected Capacity for exporting to Kahramaa network.

d) Cooperate with Kahramaa staff in all issues related to injecting electrical power into the Kahramaa network.
e) Bear all the costs associated with the connection of the Wind Turbine System to Kahramaa network.
f) Inject into the Kahramaa network the electrical power generated in excess to the local load by the Wind Turbine System according to the provisions of the *Connection Agreement*.
g) Allow Kahramaa to request a disconnection or perform an immediate disconnection of the Wind Turbine System, if its operation is expected to negatively affect the safety or the security of the power system or the Kahramaa public electricity network.
h) Develop a Maintenance manual aimed at guaranteeing the performance and the correct and reliable operation of the Wind Turbine System during its entire lifetime.

3 Abbreviations, Definitions of Terms & Key References

Abbreviations

AC	:	Alternating Current	AFCI	:	Arc Fault Circuit Interrupter
ASTM	:	American Society for Testing and Materials	$\cos\varphi$	:	Power factor
DC	:	Direct Current	GHI	:	Global horizontal irradiance
IEC	:	International Electrotechnical Commission	IP	:	Interface Protection
IR	:	Infrared	ISO	:	International Organization for Standardisation
ITP	:	Inspection and Test Plan	LOM	:	Loss of Mains
LV	:	Low Voltage (namely 220/127 V or 380/220 V or 400/230 V)	LVRT	:	Low Voltage Ride Through
MV	:	Medium Voltage (namely 13.8kV or 33 kV)	MS	:	Method Statement
NEC	:	National Electrical Code	NFPA	:	National Fire Protection Association
P	:	Active power	P_{ELV}	:	Protected Extra Low Voltage
P_{nom}	:	Nominal active power of the equipment	POA	:	Plane of Array
PPE	:	Personal protective equipment	PR	:	Performance Ratio
RCD	:	Residual Current Device	ROCOF	:	Rate of Change of Frequency expressed in Hz/s.
S/S_n	:	Apparent Power	SELV	:	Safety extra-low voltage
SPD	:	Surge Protection Device	SR	:	Soiling Ratio
STC	:	Standard Test Condition	UL	:	Underwriters Laboratories
UV	:	Ultraviolet	V_{nom}	:	Nominal Voltage
WMO	:	World Meteorological Organization	EP	:	Electricity Planning Dept
QCS	:	Quality Control System	WTG	:	Wind Turbine Generator

Term	Description
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 P_{nom} in case of the nominal active power of equipment
Apparent Power	The product of voltage and current at the fundamental frequency, and the square root of three in the case of three-phase systems, usually expressed in kilovolt-amperes (kVA) or megavolt-amperes (MVA). It consists of a real component (Active Power) and the reactive component (Reactive Power). This will be generically referred to S or S_n in case of the rated apparent power of equipment
Apparent power of an Inverter	The rated apparent power of an Inverter is the product of the rms voltage and current and is expressed in kVA or MVA.

Term	Description
Auxiliary Supply Power	Electricity supply for supporting auxiliary systems and services such as Interface Protection or circuit breaker and contactor opening coils.
Circuit Breaker (CB)	As per the Kahramaa Electricity and Wiring Code definition
Connection Point	Also referred to as *Point of Connection*, is the interface point at which a Wind Turbine System of the Customer is connected.
Consultant	A qualified consultant for the design of grid-connected WTG.
Customer	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 WTG.
Contractor	A certified contractor for the installation of grid-connected Wind Turbine Systems.
Delay time (of a protection relay)	Indicates the minimum duration of a fault detected by the protection relay before the output of the protection relay is triggered.
Delivery Point	The interface point at which electrical energy is delivered by Kahramaa to a Demand Facility or Generating Unit or by a Demand Facility or Generating Unit to Kahramaa.
Distribution System / Distribution Network	Qatar electrical infrastructure (lines, cables, substations, etc.) at 33 kV and below, operated by Kahramaa. The Distribution network can be either a Medium or Low Voltage system for the scope of the present document and in accordance with international standards: • A Low Voltage (LV) Distribution System is a network with a nominal voltage lower than 1 kV AC or 1.5 kV DC. The LV network in the State of Qatar is 240/415 V ± 6%, 3 Phase, 4 Wire. • A Medium Voltage (MV) Distribution System is a network with nominal voltage included in the range from 1 kV AC up to 33 kV. The MV Distribution System nominal voltages in Qatar are 11, 22 and 33 kV. • Electrical network voltages equal to or higher than 33 kV are not considered in this document. According to the Transmission Grid Code, the 33 kV is considered a sub-transmission network. To avoid doubt, the term Distribution Network will be preferred in this document in place of Distribution System.
Electricity Transmission Network (ETN)	Qatar electrical infrastructure (lines, cables, substations, etc.) from above 33 kV up to 400 kV operated by Kahramaa.
Global horizontal irradiance (GHI)	Direct and diffuse irradiance incident on a horizontal surface expressed in W/m^2.
Inspection	Examination of an electrical installation in order to ascertain correct selection, design and proper erection of electrical equipment.
Interface protection (IP)	Electrical protection part of the Wind Turbine System that ensures the WTG is disconnected from the network in case of an event that compromises the integrity of Kahramaa's distribution network.
Inverter	Electric energy converter that changes direct electric current to single-phase or polyphase alternating current.
Irradiance (G)	Incident flux of radiant power per unit area expressed in W/m^2.
Irradiation (H)	Irradiance integrated over a given time interval and measured in energy units (e.g., $kWh/m^2/day$).
Islanding	Situation where a portion of the distribution network containing generating plants becomes physically disconnected from the rest of the distribution

Term	Description
	network. One or more generating plants maintain electricity supply to such isolated parts of the distribution network.
Load Flow	It is a numerical analysis of the electric power flow in a transmission and/or distribution systems. A power-flow study usually uses simplified notations such as a one-line diagram and per-unit system, and focuses on various parameters, such as voltages, voltage angles, real power and reactive power. It analyses the power systems in normal steady-state operation.
Loss Of Mains (LOM)	Represents an operating condition in which a distribution network, or part of it, is separated from the main power system (on purpose or in case of a fault) with the final aim of de-energisation. The protection that detects this condition is known as anti-islanding protection.
Main Meter	It is the bidirectional smart meter installed at the Connection Point which measures the amount of electric energy actually exchanged (import or export) by the Customer with the distribution network.
Maximum Capacity (P_{max})	It is the maximum continuous active power which a Generating Unit can produce, less any auxiliary consumption associated used to facilitate the operation of that Generating Unit. The Maximum Capacity shall not be fed into the distribution network as specified in the *Connection Agreement*. In this document, this term is also referred to as Maximum Connected Capacity.
National Control Centre (NCC)	Main Kahramaa's facility used to operate and control/maintain the Electric Power System.
Peak Power (Wp)	The output power achieved by a Photovoltaic Module under Standard Test Conditions (STC). It is measured in W_p (W peak). The sum of the peak power of the photovoltaic modules of either a string or an array determines the peak power of the string and the array, respectively (usually measured in kW_p). The peak power of a photovoltaic array at STC is conventionally assumed as the rated power of the array.
Power Factor	It is the ratio of Active Power to Apparent Power.
Power Park Module (PPM)	A unit or ensemble of units generating electricity, which is either non-synchronously connected to the network or connected through power electronics, and that also has a single Connection Point to the ETN.
Rated Active Power	Represents the sum of the nominal active power of all the Wind Turbine Units which compose the Wind Turbine System; it is generally referred to as Pnom of the Wind Turbine System
Reactive Power	Represents a component of the apparent power at the fundamental frequency, usually expressed in kilovar (kVAr) or Megavar (MVAr).
Reactive Power Capability	Defines the reserves of inductive/capacitive reactive power which can be provided by a generating system/unit. The reactive power capability usually varies with the active power and the voltage of the generating system/unit.
Residual Current Device (RCD)	A sensitive switch that disconnects a circuit when the residual current exceeds the operating value of the circuit, referred as RCD in this document.
Switch	As per the Kahramaa Electricity and Wiring Code definition.
Testing	Implementing measures in an electrical installation to prove its effectiveness (Note: It includes ascertaining values using appropriate measuring instruments, said values not being detectable by inspection).
Time Current Curve (TCC)	The time current curve plots the interrupting time of an overcurrent device based on a given current level. These curves are used for the protection

Term	Description
	coordination and are provided by the manufacturers of electrical overcurrent interrupting devices such as fuses and circuit breakers.
THD (Total Harmonic Distortion)	Concerning an alternating quantity, it represents the ratio of the r.m.s. value of the harmonic content to the r.m.s. value of the fundamental component or the reference fundamental component.

Key References

[1] The Qatar Transmission Grid Code – Issue ES-M4 – Revision 0.0 – March 2020 and amendments in force until 02/2022 (in this document referred to as “Transmission Code”)
[2] CS-CSI-P1/C1 Kahramaa’s Low Voltage Electricity Wiring Code 2016
[3] Safety Rules for the Control, Operation and Maintenance of Electricity Transmission & Distribution System of Qatar General Electricity & Water Corporation.
[4] System Operation Memorandum (SOM).
[5] Kahramaa interlocking document, (Qatar Power Transmission System Expansion – Latest phase – Substations).
[6] Qatar Construction Specifications latest edition
[7] ET-P26-G1 Guidelines for Protection Requirements.
[8] ES–EST-P1-G1 Guidelines for System Control Requirements for Power Supply to Bulk Customers.
[9] ET-P20-S1 Transmission Protection Standards for TA and ET Projects.
[10] ES-M2 Qatar Power System Restoration Plan; and
[11] ES-M3 System Emergency, Categorization, Communication & Restoration Responsibility.
[12] QCDD (Qatar Civil Defence Department) regulations
[13] CS-CSI-P2 E_W – Infrastructure Preparation for Service Connection Purpose v3
[14] CS-CSI-P3 E_W – Services Inspection v5
[15] CS-CSI-P4 – Low Voltage Electrical Contractor Licensing v3
[16] CS-CSI-P5 – Handling of Contractors Violations Procedure v2
[17] CS-JCU-P1 – Illegal Connections Reconnections v3
[18] CS-CSM-P2 E_W – Supply Connection and Disconnection
[19] CS-AMI-P1 – AMI Operations
[20] CS-MAS-P2 E_W – Meter Installation v4
[21] CS-MAS-P3 – Maintenance of Electricity and Water Meter v2
[22] CS-MAS-P5 – Materials Submittal Review _ Approval Procedure v2
[23] Energy and Water Conservation Code 2016
[24] EP-EPD-P1 – Electricity Supply Approval v3
[25] EP-EPD-P4 – Processing Service Notes v2
[26] EP-EPD-P6 11kV – Load Flow Study v2
[27] EP-EPP-C1 – Electricity Planning Regulations for Supply
[28] EP-EPP-P3 – Early Arrangement for Supply Connection
[29] EP-EPP-P5 – Electricity Supply Application
[30] EP-EPT-P2 – Basic Concept Report-Direct Connection Notification
[31] EP-EPT-P3 – Peak Demand Forecast
[32] EP-EPT-P4 – Power System Studies and Five Years Development Plan
[33] ES-ESN-P3 – Dispatching Procedure
[34] ES-ESN-P4 – Bulk Industrial Customers Energy Meter Readings Collection v2
[35] ES-ESP-P1 – Creating Operational Load Forecast
[36] ES-ESP-P2 – Long Term Operation Planning
[37] ES-ESP-P3 – Develop Monitor Energy Purchase Schedules and Allocation Plans
[38] ES-ESP-P4 – Operation Studies
[39] ES-ESP-P7 – Develop Surplus Available Capacity Plan for Marketing
[40] ES-M4 – Qatar Transmission Grid Code 2020
[41] ET-P26 ETD – Responsibilities for Bulk Customer’s Request for Supply of Electricity

[42] CS-CSB-P1 – Bulk Supply of Electricity and Water
[43] PW-PWP-P1 E_W – Demand Forecasting
[44] PW-PWP-P2 – Additional Capacity Planning
[45] PW-PWP-PL1 – Planning _ Procurement Policy
[46] PW-PWR-P2 – Renewable Energy Standards Development.

DISCLAIMER

The latest editions of the Transmission Grid Code, the Electricity Wiring Code, Qatar Construction Specifications, as well as all the documents indicated in the above list in force at the time of the contract, must prevail and should be complied with. The Customer shall also comply with the requirements of any standards issued by Qatar Authorities at the time of the Connection Purchase Agreement.

Applicable Standards for Wind Turbine Systems Components

Along with the Technical Specifications for the Connection described in the current document, all the components of the Wind Turbine Systems must comply with the applicable International and Qatar standards listed here below.

This ensures that all the components and equipment deployed for developing the Wind Turbine Systems connected to the Qatar grids comply with a minimum set of technical requirements, which assure the compliance of materials, components, and equipment with standard quality levels, hence avoiding using inadequate or unreliable solutions in Wind Turbine projects.

However, technical standards may be subject to future revisions, amendments, or extensions, and it will be the User's care finding the latest published versions and utilise them.

WIND TURBINES

- IEC 61400-1:2019 – Wind energy generation systems – Part 1: Design requirements.
- IEC 61400-2:2013 – Wind turbines – Part 2: Small wind turbines.
- IEC 61400-4:2012 – Wind turbines - Part 4: Design requirements for wind turbine gearboxes.
- IEC 61400-8: Wind Energy Generation System-Design of Wind Turbine Structural Components.
- IEC 61400-11:2012+AMD1:2018 CSV – Wind turbines - Part 11: Acoustic noise measurement techniques.
- IEC 61400-12-1:2017 – Wind energy generation systems – Part 12-1: Power performance measurements of electricity producing wind turbines.
- IEC 61400-15-1: Site Suitability input Conditions for Wind Power Plants.
- IEC 61400-21-1:2019 – Wind energy generation systems – Part 21-1: Measurement and assessment of electrical characteristics – Wind turbines.
- IEC 61400-23 Full Scale Structural Testing of rotor blades.
- IEC 61400-24:2019 – Wind energy generation systems – Part 23: Lightning protection.
- IEC 61400-25-2: Communication for monitoring and Control of Wind Power plants Information Models.
- IEC 61400-26-4: Reliability for Wind Energy Generating System.

- IEC 61400-29: Marking and lighting of WEGS.
- IEC 61400-30: Safety of Wind turbine Energy Generating System.
- IEC 61400-31: Siting Risk Assessment.
- IEC 61400-40: Electromagnetic Compatibility (EMC) Requirements and Test Methods.
- IEC 61400-101: General Requirements for Wind Turbine plants.
- IEC 61000-3-2:2014 – Electromagnetic compatibility (EMC) - Part 3-2: Limits - Limits for harmonic current emissions (equipment input current ≤ 16 A per phase).
- IEC 61000-3-3:2013 - Electromagnetic compatibility (EMC) - Part 3-3: Limits - Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤16 A per phase and not subject to conditional connection.
- IEC 61000-3-12:2011 – Electromagnetic compatibility (EMC) - Part 3-12: Limits - Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current >16 A and ≤ 75 A per phase.
- IEC 61000-3-11:2017 – Electromagnetic compatibility (EMC) - Part 3-11: Limits - Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems - Equipment with rated current ≤ 75 A and subject to conditional connection.
- IEC-62305 – Lightning Protection
- IEEE 80 – Safety in Earthing and grounding
- IEC – 62305-2- Risk management
- IEC – 62305 -3- Physical damage to structures and life hazard
- IEC – 62305 -4- Electrical and electronic systems within structures

  Considering that this is a connection document, some additional standards regarding the design (corrosion) of the Wind Turbine Systems are listed in ANNEX F.

INTERFACE PROTECTION

- IEEE 1547-2018 – IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces
- IEEE 1547.1-2005 - IEEE Standard Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems
- IEEE 1547.1-2015 - IEEE Standard Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems - Amendment 1

DISCLAIMER

The listed standards are related only to the main Wind Turbine System equipment. Standards for other electrical components, such as transformers, circuit breakers, switchgears, etc., must follow the technical standards accepted and approved by the Kahramaa in the applicable regulations.

4 Technical Requirements

4.1 General requirements

A Wind Turbine System can be connected to Kahramaa Distribution Networks, either LV or MV, at an appropriate point called *Connection Point*. It is under the responsibility of Kahramaa determining the appropriate Connection Point, assessing the capacity of his network in hosting the considered Wind Turbine System at that point whilst guaranteeing a stable, secure and reliable grid operation for all the possible operating conditions.

According to the Transmission Code, if the results of such assessing process determine that the considered Wind Turbine System could led the distribution network to operate outside the Kahramaa statutory performance standards, Kahramaa has the right to reject the connection application or to propose modifications (for example in terms of Connection Point and/or characteristics of the Wind Turbine System) or alternative solutions (for example in terms of network reinforcements) aimed at enabling the connection.

The Maximum Connected Capacity of the Wind Turbine System to be proposed by the Customer will be determined in agreement with the applicable clauses of the Power and Water Purchase Agreement (PWPA) and Qatar Transmission Grid Code.

4.2 Connection Schemes

A Wind Turbine System must comply with the connection requirements defined by Kahramaa, and in particular, it must meet the following minimum requirements:

a) The synchronisation, operation, and disconnection of the Wind Turbine System under normal network operating conditions, i.e., in the absence of faults or malfunctions, must bear no consequences to the power quality of the network as established in Section D2.6 of the Qatar Transmission Grid Code.
b) The protection schemes and settings needed for the Wind Turbine System should be coordinated with the distribution network protection. Kahramaa and the Customer (through his Consultant/Contractor) should define the protection settings coordination according to the following requirements:
    - Faults and malfunctions within the Wind Turbine System must not impair the normal operation of Kahramaa distribution network. In particular, any faults that include earth faults with leakage current internal to the Customer's installation must be detected and cleared below or at the connection point before the operation of any Kahramaa protection system.
    - The protection schemes and settings for electrical faults within the Customer's installation must not affect the performance of the Wind Turbine System.
    - The protection schemes of the Wind Turbine System should be coordinated with those of the distribution network in order to properly coordinate the protection systems operation in the presence of faults either within the Wind Turbine System or within the distribution network.

To satisfy the above requirements, Figure 1 and Figure 2 present the typical equipment which, at least, should be installed for a safe and reliable interconnection of a Wind Turbine System to the LV and MV distribution network.

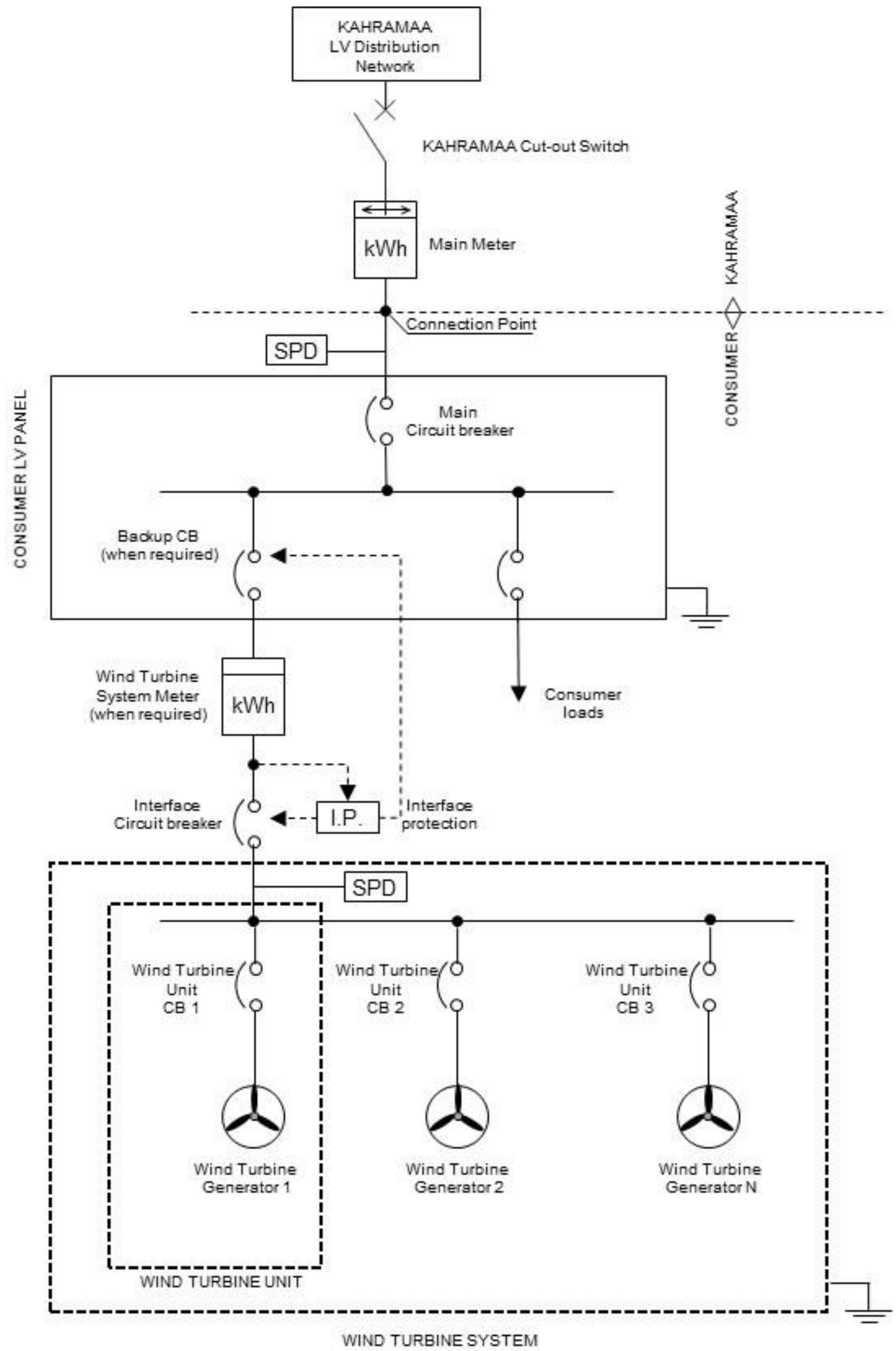


Figure 1: Schematic representation for the connection of a Wind Turbine System to LV Distribution Network

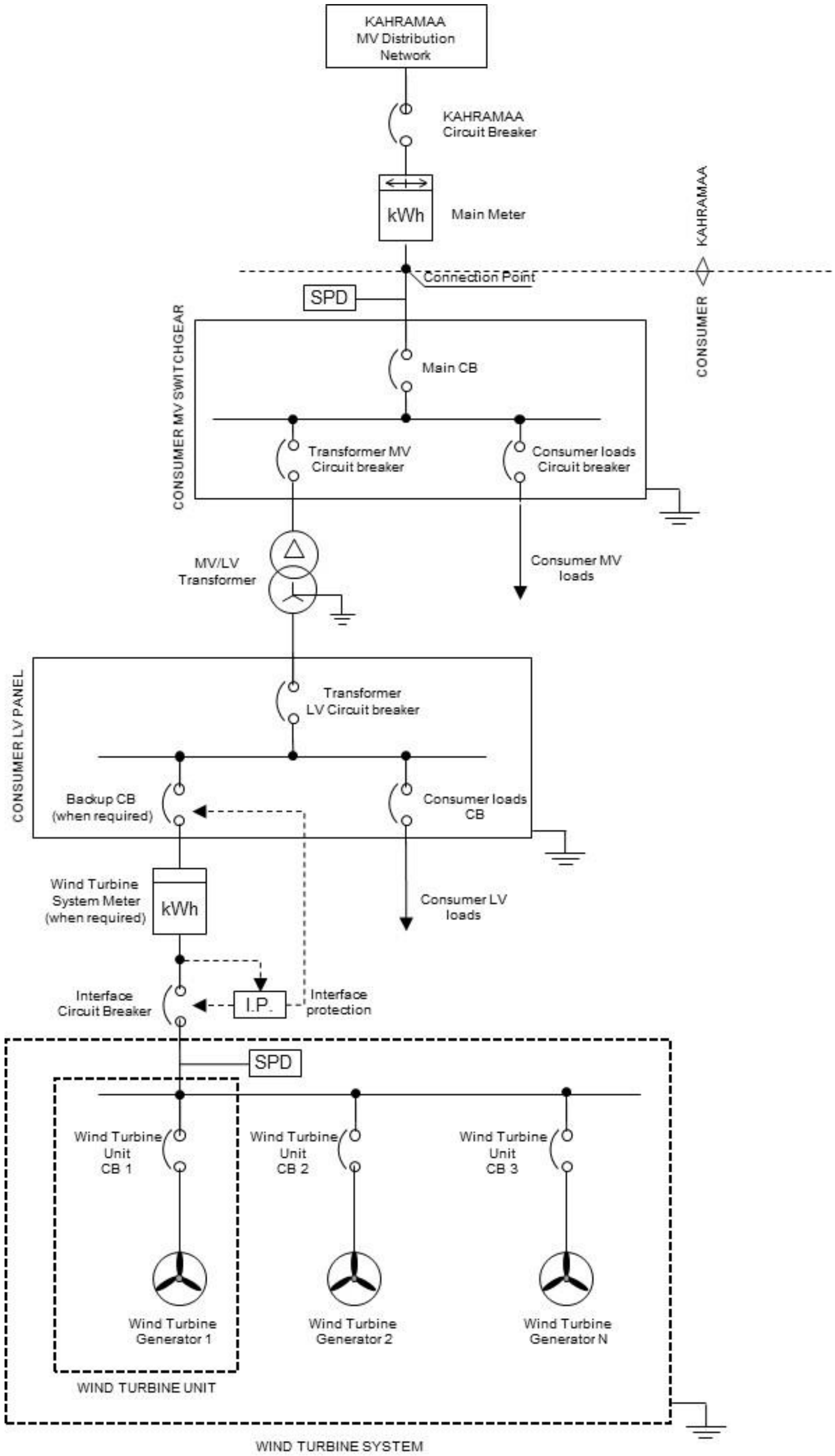


Figure 2: Schematic representation for the connection of a Wind Turbine System to MV Distribution Network

The typical equipment represented in Figure 1 and Figure 2 include the following components:

a) The Main Circuit Breaker, which should be installed as close as possible to the *Connection Point* and operated by a protection system in the case of internal faults. If agreed with Kahramaa, it is possible to install more than one main circuit breaker in order, for example, to have two separate circuits, one dedicated to the Customer's local loads and one dedicated to the Wind Turbine System. An example of this scheme is reported in Figure 13, ANNEX A.

b) The Interface Circuit Breaker, which should be operated by an Interface Protection, must be envisaged in the Customer installation to separate the plant portion containing one or more Wind Turbine Units from both the plant portion feeding the local loads and the Kahramaa distribution network. For Wind Turbine Systems whose rated power exceeds 20 kW, a Backup Circuit Breaker is required in order to operate in the presence of an opening failure of the Interface Circuit Breaker.

c) The Wind Turbine Unit Circuit Breaker, which should be installed as close as possible to the terminals of each Wind Turbine Unit for its protection and connection/disconnection. As far as the protection issues are concerned, the recommendations and requirements defined by the equipment manufacturer should be applied.

ANNEX A describes typical connection schemes that can be adopted for connecting a Wind Turbine System to Kahramaa Distribution Network. Different solutions may be used if previously agreed with Kahramaa.

DISCLAIMER

If the inverters/converting station ***nominal voltage does not match the nominal voltage of the distribution Network, a transformer must be installed for the grid connection of either the Wind Turbine System or each single Wind Turbine Unit. The cost of this transformer must not be ascribed for any reason to Kahramaa and must be entirely supported by the Customer.***

The wind turbines are expected to draw current from grid during their start-up. The corresponding power demand profiles depends on the blades mass and the generator technology. In any cases, and if technically possible, wind turbines starting should be managed by soft starters, which should assure that the rate at which the power is ramped up after a system fault or during start-up should not cause significant power surges. Wind turbine should not be started if the grid frequency is above 51.5 Hz. It is also highly recommended to select, as preferred options, type 3 or type 4 turbines, rather than outdated technologies (i.e., type 1 and type 2).

4.3 Circuit Breakers Selection

DISCLAIMER

In this document and the Single Line Diagrams, the nomenclature, and symbols of the Kahramaa Electricity Wiring Code were used for the protection/disconnection (under normal and fault conditions) and insulation of the Wind Turbine Systems. These circuit breakers are just indicative and, for that reason, should be carefully considered by the Consultants during their design according to the specific case and need. These circuit breakers cannot be directly applied or copied by the Consultant without conducting a technical assessment for the specific Wind Turbine System they are designing. They have to be replaced by the proper symbol and disconnection device following what is established in Kahramaa's Electricity Wiring Code.

This circuit breaker, and its corresponding symbol, should be replaced by the proper device as per the Electricity Wiring Code, depending on design choices made by the Wind Turbine System designer (Consultant / Contractor).

For each of the circuit breaker mentioned above, the choice of the type to be installed should be based on:

- The functions that the circuit breaker should perform.
- The features of the Customer's installation.
- The features of the Kahramaa Distribution Network at the Connection Point.

Especially, the following criteria should be adopted:

- The circuit breakers, panels and switchgear must be compliant with the requirements defined in the Transmission Code,
- The circuit breaker(s) of the Wind Turbine Unit(s) must be compliant with the requirements defined by the corresponding Manufacturers,
- Electronic switches must not be used for protective functions (e.g., overcurrent/earth protection).
- For Wind Turbine Systems connected to the MV Distribution Network and with the Interface Circuit Breaker on the MV side of the plant (see Figure 17 in ANNEX A), the Interface Circuit Breaker must be a three-pole automatic circuit breaker operated by an undervoltage relay along with an isolator (either upstream or downstream of the circuit breaker).

  The above requirement should be incorporated into the standard type of panels for MV applications approved by Kahramaa.

  Considering the requirement for distributed generation, a new standard type of Switchgear panel should be designed. In the case of MV panels, a dedicated panel type should be proposed by the Consultant/Contractor with the required protection & control functions, which should be suitable for such applications.

  The consensus to the reclosure of the Interface Circuit Breaker must be given by the Interface Protection itself, which should be able to sense the voltages on the network side (as represented in the Connection Schemes, Figure 16 and Figure 17) and not on the Wind Turbine System side of the Interface Circuit Breaker.

- For Wind Turbine Systems connected to the MV Distribution Network and with the Interface Circuit Breaker on the LV side of the plant (see Figure 16 in ANNEX A) or for Wind Turbine Systems connected to the LV distribution network (see schemes from Figure 11 to Figure 15 in ANNEX A), the Interface Circuit Breaker must consist of a motorised automatic circuit breaker to allow the automatic reclosure once the network disturbances that have led the Interface Protection tripping have been cleared. The consensus to reclosure of the Interface Circuit Breaker must be given by the Interface Protection itself, which should sense the voltages on the network side (as represented in the Connection Schemes, from Figure 11 to Figure 15) and not on the Wind Turbine System side of the Interface Circuit Breaker.

- Any circuit breaker should have a proper breaking and making capacity, which must be coordinated with the rated values of the Customer's installation, considering both the Wind Turbine System and the contribution to the short circuit from the Distribution Network.
- The short-time withstand-current of the switching devices must be coordinated with the maximum short circuit current/power at the Connection Point1.
- In case of loss of auxiliary supply power to the switchgear, a prompt, reliable and secure disconnection of the Interface Circuit Breaker is immediately required.

The Interface Circuit Breaker function can be combined with either the Main Circuit Breaker or the Wind Turbine Unit Circuit Breaker in a single switching device[2]. In that case, the single combined switching device must be compliant with both the requirements of the Interface Circuit Breaker and of either the Main Circuit Breaker or the Wind Turbine Unit Circuit Breaker, according to the chosen combination. Consequently, at least two circuit breakers in series must always be present between a Wind Turbine Unit and the Connection Point. For further details, please refer to the indicative Connection Schemes reported in ANNEX A.

4.4 Protection against Faults

The electrical protections required for connecting a Wind Turbine System to the Kahramaa Distribution Network are also defined in the present document. These additional protections should be checked and approved by Kahramaa. Other protections should also be installed to protect the Customer's electrical assets according to the Kahramaa protection policies. All protections should be graded and coordinated with all the Kahramaa upstream protections and downstream protections within the Wind Turbine installation. Any faults down to the Connection Point must be cleared at the same point (or below) without impacting the correct operation of the Kahramaa distribution network.

Where **overcurrent and earth protection** are required for equipment safety, whether this be part of the Wind Turbine System or not, automatic disconnection of the faulted circuit should be accomplished.

The Customer must comply with the relevant Kahramaa material standards & specifications and the applicable requirements and specifications of the latest issue of Kahramaa Protection Guidelines/Standard ET-P26-G1 (Guidelines for Protection/Energy meter requirements for Power supply to Bulk Customers).

At the initial stage of the project any deviations from the applicable technical standards must be immediately notified to Kahramaa for reviewing and approval.

[1] Kahramaa should deliver to the Demand Facility Owner an estimate of the minimum and maximum short-circuit currents expected at the connection point (distribution network contributions).

[2] For connection schemes using a single main switch, the combination of the interface switch with the main switch will lead to the disconnection of the overall Customer's facility when the interface switch is opened, that is a lack of supply that also affect the Customer load.

The Customer should provide the required new protection or modify existing protection of the Kahramaa interfacing bays.

The Customer should coordinate the protection schemes and settings relevant to the Demand Facility with Kahramaa.

Kahramaa will review the Connection Equipment protection scheme and settings. The protection and settings of all other equipment and circuits in the Demand Facility are under the responsibility of Demand Facility Owners.

Protection schemes and devices should cover the following events and equipment:

1. External and internal short-circuits
2. Over- and under-voltage at the Delivery Point to the ETN
3. Over- and under-frequency
4. Demand circuit (cable/line)
5. Transformer
6. Switchgear malfunction
7. Circuit Breaker failure
8. Busbar
9. Surge protection device

Customer should install mandatory Protections for interfacing bay at both ends and implement the required modifications to match the local end of Kahramaa Substations' remote end.

The protection document required by Kahramaa at each stage of the project must be submitted to Kahramaa for review/approval/record.

Electrical protection of the Customer's Facility should take priority over operational controls, while respecting power system security, health, and safety of both the staff and the peoples. Kahramaa and the Customer should agree on any changes to the approved protection schemes.

The maintenance of all the protection equipment at the premises of the Demand Facility, including those of the Connection equipment, is under the Customer's responsibility in coordination with Kahramaa, as applicable.

The Customer must comply with Kahramaa Interlocking requirements and should test such interlocking in presence of Kahramaa's staff.

4.5 Operating Ranges

Regardless of the type and settings of the protection systems, the Wind Turbine System should be capable of remaining connected to the Distribution Network, assuring its stable operation, for the frequency and voltage ranges and the corresponding time periods specified in the following tables, and summarized in Figure 3.

Table 1: Frequency operating range

Frequency Ranges	Time periods for operation
47.5 Hz – 49.5 Hz	Maximum 30 min
49.5 Hz – 50.5 Hz	Unlimited
50.5 Hz – 51.5 Hz	Maximum 30 min

Table 2: Voltage operating range

Voltage Level (1 pu)	Voltage range	Time period for operation
11 kV – 33 kV (limited to 33 kV as per this document scope)	0.85 pu - 0.90 pu	Maximum 30 min
	0.9 pu – 1.1 pu	Unlimited
	1.1 pu - 1.15 pu	Maximum 30 min

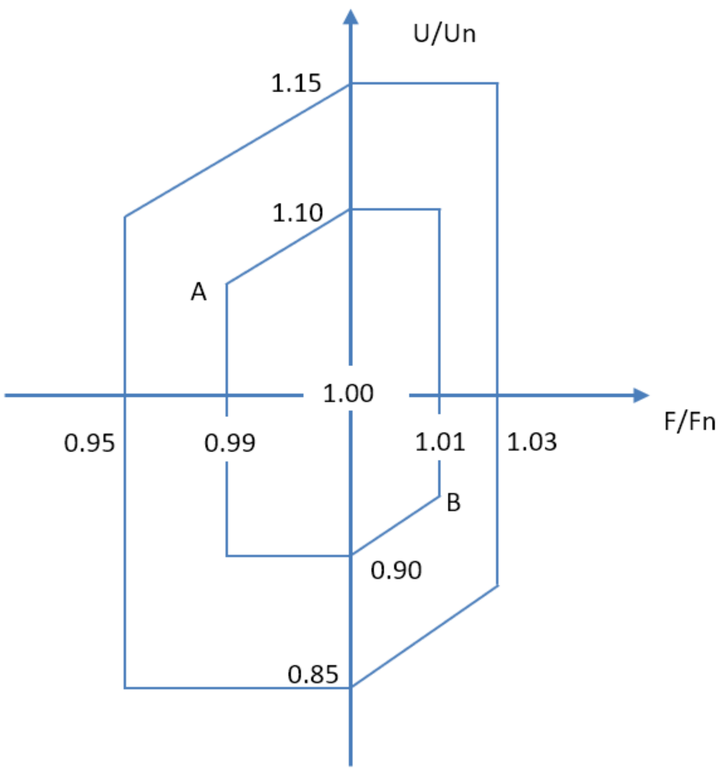


Figure 3: Voltage and Frequency Operating Range

4.6 Immunity to Disturbances

The Wind Turbine System should be able to withstand credible fault conditions and support the network voltage recovery. If the generation system is unable to comply with the requirements defined in the following Sub-Sections (e.g. it integrates Type 1 or Type 2 wind turbines), it should be equipped by specific auxiliary devices such as series connected auxiliary devices (e.g. Thyristor-Controlled Series Compensation, Dynamic Voltage Restorer), shunt-connected auxiliary devices (e.g. Static Var Compensator, Static Synchronous Compensator, Unified Power Quality Conditioner), or a proper combination of these devices.

4.6.1 Low Voltage Ride Through (LVRT) Capability

Wind Turbine Systems should contribute to enhancing the overall power system stability by providing robustness against dynamic voltage changes, especially those induced by faults on higher voltage level networks. The corresponding requirements apply to all kind of disturbances (1ph, 2ph and 3ph faults) and are independent of the Interface Protection settings (see 4.9.4), which overrule the technical capabilities of the Wind Turbine System, affecting its grid connection status.

A Wind Turbine System with a Maximum Connected Capacity greater than 11kW should be capable of remaining connected to the distribution network as long as the voltage at the Connection Point remains above the voltage-time diagram reported in Figure 4. , where the p.u. voltage magnitude shall be referred to the nominal voltage at the Connection Point. For three-phase generating systems, the smallest phase to phase voltage should be evaluated. The compliance to this LVRT requirement must be verified for all equipment that might cause the disconnection of the Wind Turbine System, i.e., Wind Turbine Generators and Interface Protection.

After the fault is cleared and the voltage returned within the normal operating range (see 6.5), the pre-disturbance operating conditions (active & reactive power) shall be recovered as fast as possible with a tolerance of ±10% of the Wind Turbine System rated power.

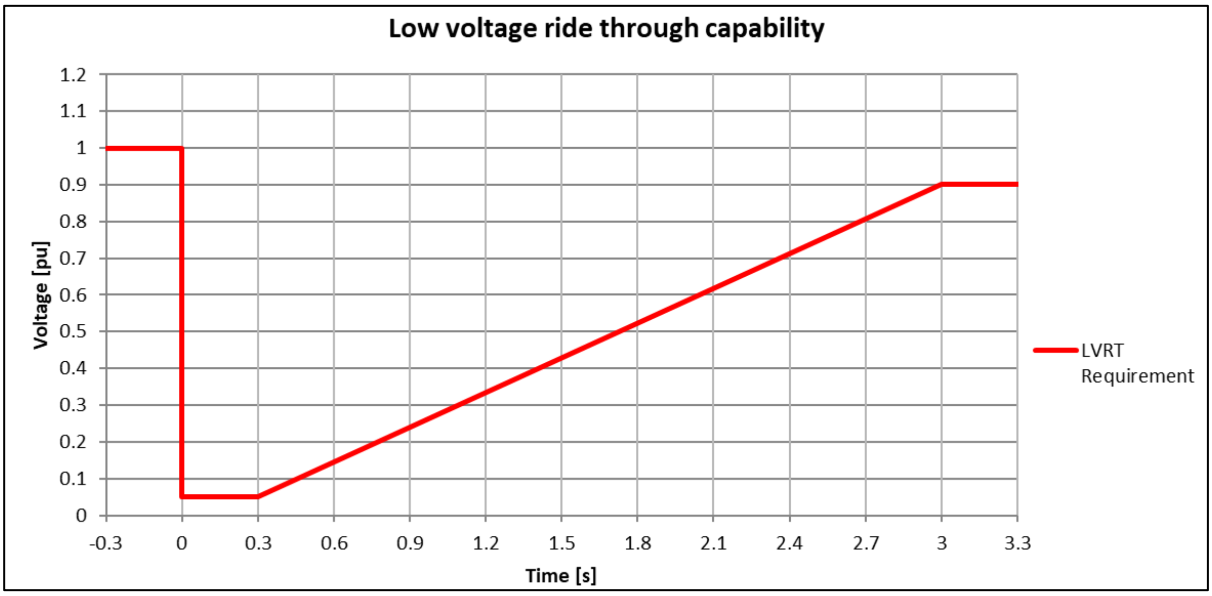


Figure 4: LVRT characteristic for Wind Turbine System with a Maximum Connected Capacity greater than 11kW

4.6.2 ROCOF Withstand Capability

The Wind Turbine Systems, when generating power, shall be able to go through frequency transients with frequency within the normal operating range (see 4.5) and with ROCOF value up to 2.5 Hz/s [3].

In the case that the Loss of Mains (LOM) protection implements a ROCOF-based method (as described in 4.9.4), the threshold of the LOM function shall not cause the intervention of the protection within the immunity ranges as specified in this paragraph.

4.7 Requirements for the Frequency Stability of the Power System

If technically feasible, the Wind Turbine Systems should actively contribute to improve power system stability by active power control reacting to frequency variations and remote limitation of active power, according to the following requirements.

4.7.1 Active Power Response to Frequency Variations

A Wind Turbine System shall be capable of activating the provision of active power response to over-frequency transients according to the curve of Figure 5, where the frequency threshold and the droop settings should be fixed according to reference values specified by Kahramaa, and in particular:

- The frequency threshold should be settable at least between 50 Hz and 52 Hz inclusive; if not differently specified by Kahramaa, the threshold should be set to 50.5 Hz.
- In case of deviation of the network frequency above 51.5 Hz, the Wind Turbine System shall disconnect from the Transmission Network.
- The generated active power P_{gen} shall be referred to as the actual active power value P_{act} when the threshold is reached, and the active power response is activated.
- the Generating Units shall be capable of activating the provision of active power frequency response according to Figure D.2-2 of the Transmission Grid Code at a frequency threshold between 50.2 Hz and 50.5 Hz inclusive and Droop settings between 2 % and 12 % specified by Kahramaa.

The resolution of the frequency measurement shall be ±10mHz or less. The active power response should be activated as fast as possible and delivered with an accuracy of ±10% of the nominal power.

[3] It is recommended to measure the ROCOF over a sliding 500ms time period.

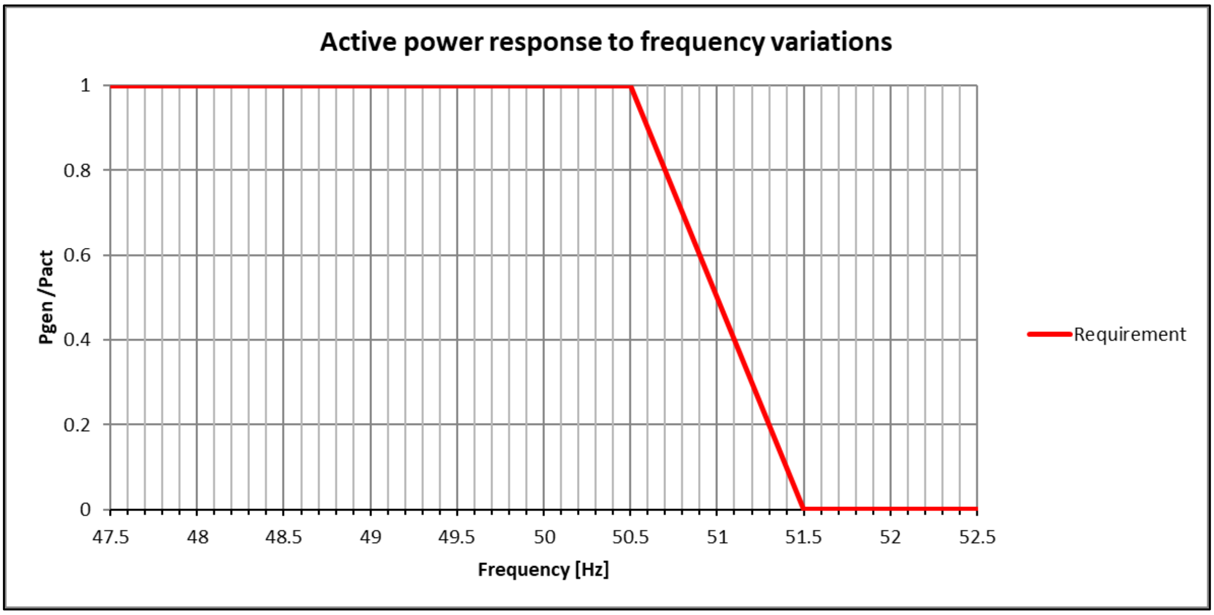


Figure 5 - Active power frequency response for Distributed Wind Turbine System

4.7.2 Active power delivery at under-frequencies

When a Wind Turbine System works in under-frequency operating conditions due to the Distribution Network, the reduction of the maximum active power shall be kept as low as technically feasible; in any case, it should satisfy the minimum requirements defined in Figure 6.

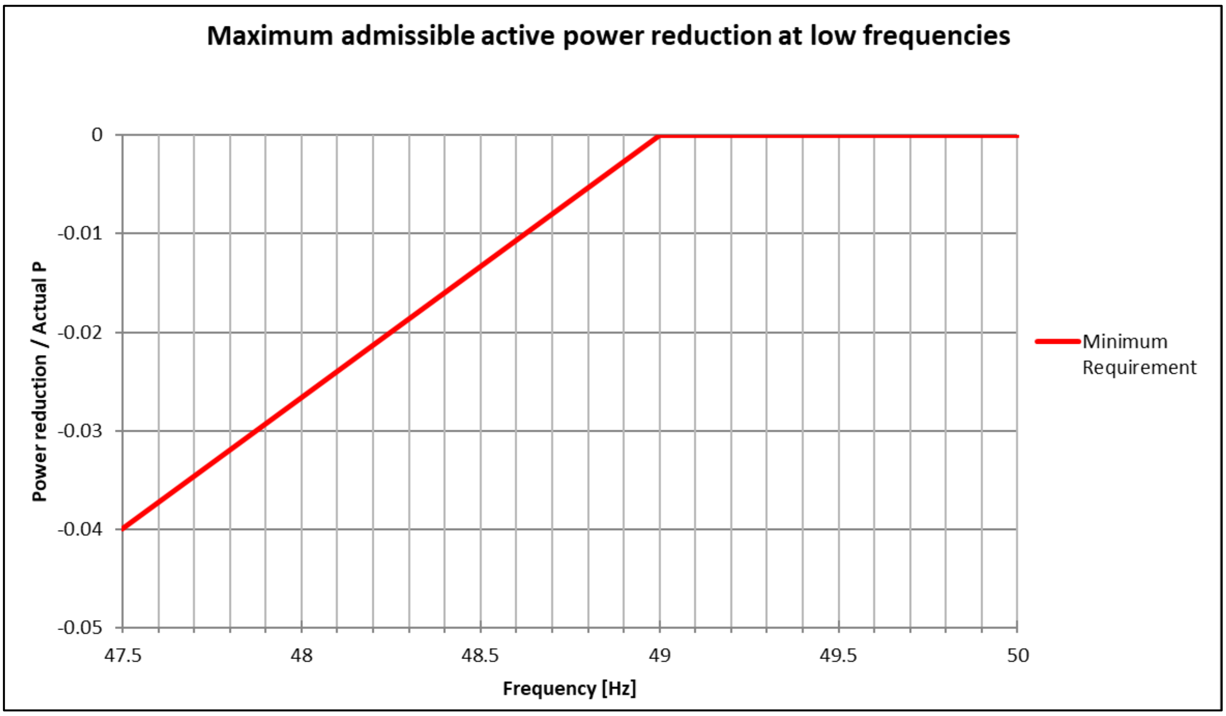


Figure 6: Maximum permissible output power reduction at under- frequencies

4.7.3 Remote Limitation of Active Power

A Wind Turbine System with a Maximum Connected Capacity greater than 11 kW shall be equipped with an interface (input port) that is able to receive, from a remote-control centre, an instruction requiring the reduction of the active power output.

The reduction of active power should be carried out as fast as possible and with an accuracy greater than 5% of the nominal active power of the Wind Turbine System.

Kahramaa must have the right to specify further requirements in terms of equipment, communication protocol, information to be exchanged and/or time of execution, which allow integration of such features into the control systems of its Distribution Network, and which allow to remotely limit the active power output of the Wind Turbine Units connected to its network.

4.8 Requirements for the Voltage Stability of the Power System

Requirements as per Transmission Grid Code, par. D.3.4 shall apply.

4.8.1 Reactive Power Capability

When voltage and frequency at the Connection Point are within their normal operating ranges, a Wind Turbine System should be able to provide reactive power in any operating point within the boundaries of the reactive power capability curves defined in Figure 7 [4] and Figure 8.

According to this capability, the inverters/converting station will either generate or absorb inductive reactive power from the Distribution Network to participate in voltage support at the Connection Point for any of the values of active power generated by the Wind Turbine System.

Three areas are visible in Figure 7:

a) Triangular area, required for inverters/converting station included in Wind Turbine Systems whose Maximum Connected Capacity is smaller than or equal to 11 kW: for an active power ranging from zero to the nominal power of the Wind Turbine System (i.e., 1 p.u.), the Inverter/converting station should be capable of either generating or absorbing inductive reactive power Q at a power factor $\cos\varphi$ of 0.95 (boundary points of the triangular curve in the chart);

b) Rectangular area required for inverters/converting station included in Wind Turbine Systems whose Maximum Connected Capacity is greater than 11 kW: these should be capable of either generating or absorbing inductive reactive power Q within the area. For a value of 1 p.u. of active power, that is, when the generated power is equal to nominal power, this corresponds to a power factor $\cos\varphi$ of 0.95 (apex points of the rectangular area for P = 1 p.u.).

c) Design free area which can be optionally exploited by the Inverter/converting station Manufacturers.

Concerning Figure 7, when the Wind Turbine System operates in the design-free area (i.e., above its nominal active power because of favourable environmental conditions), it is allowed reducing the reactive power capability according to the widest possible technical capability of the Wind Turbine Units.

When the Wind Turbine System operates above a threshold of 10 % of its nominal apparent power Sn, the required reactive power Q shall be provided with an accuracy of ±2% S_n. Below the threshold of 10% of S_n, deviations above 2% of accuracy are

[4] The active power 1 p.u. shall refer to the nominal active power value of the Wind System: at 1 p.u. of active power, the reactive power capability of a Wind System corresponds to a power factor varying between 0.95 leading (inductive reactive power absorbed) to 0.95 lagging (inductive reactive power generated).

permissible; nevertheless, the accuracy shall always be as good as technically feasible and shall not exceed 10% of S_n.

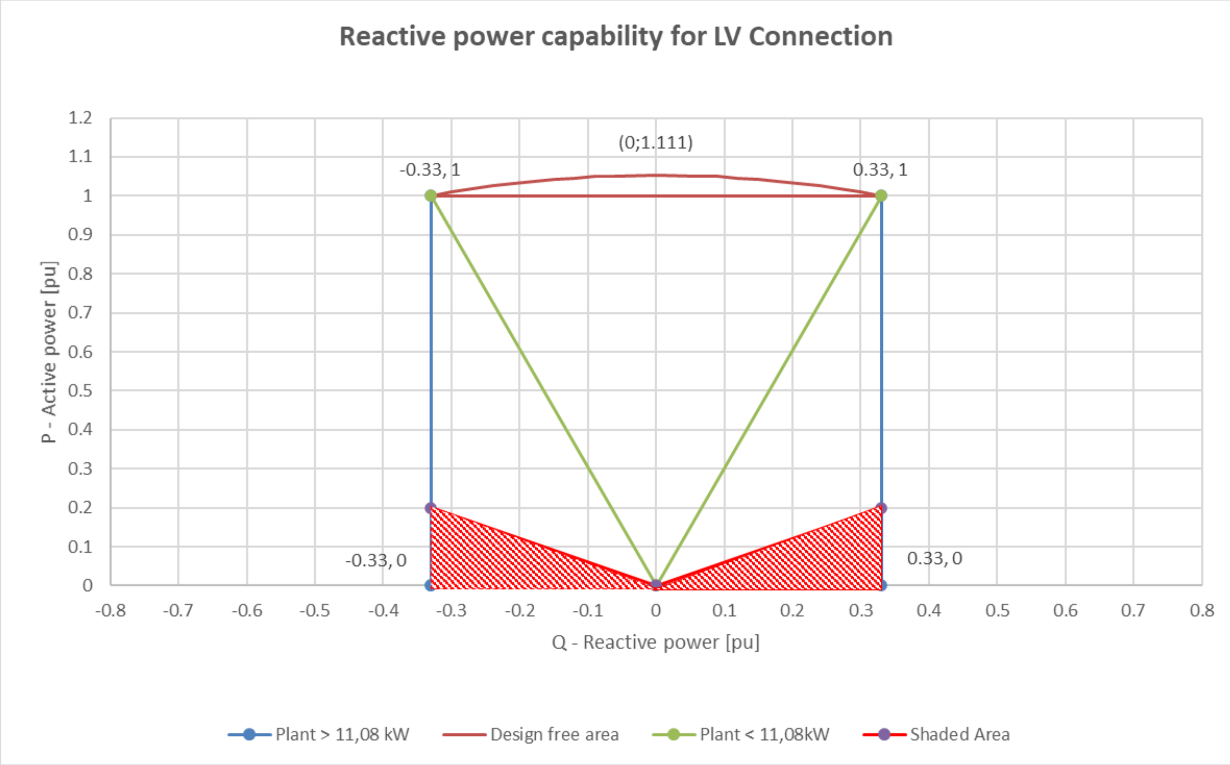


Figure 7: Reactive power capability at Point of Connection

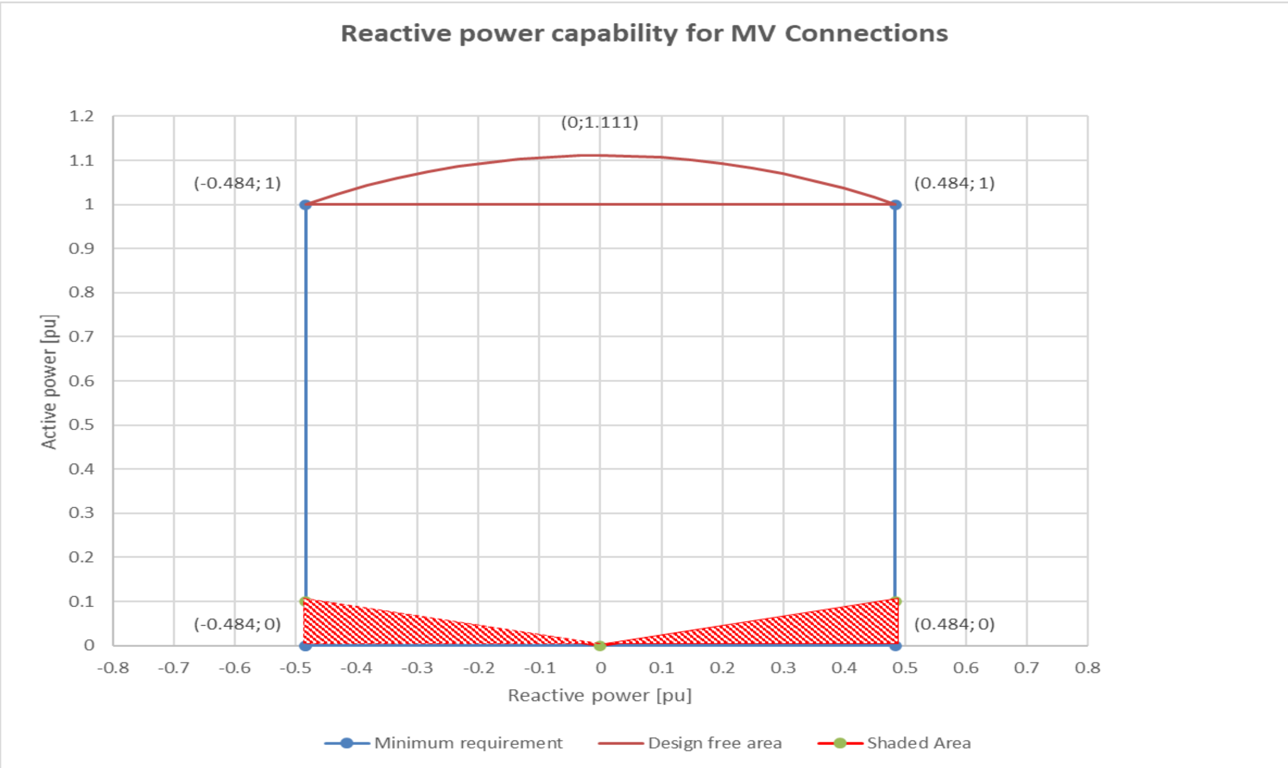


Figure 8. Reactive power capability For MV connection

4.8.2 Reactive Power Control Modes

A Wind Turbine System should be capable of operating in the control modes stated below, within the limits of its reactive power capability as expressed in 4.8.1:

fixed *Q*: the reactive power is controlled to obtain a fixed value.

fixed *cos φ*: the reactive power is controlled to obtain a fixed power factor.

cos φ (P): the reactive power is controlled to obtain a power factor that is a function of the actual active power delivery.

Q = f(V): the reactive power is controlled as a function of the local voltage, according to a characteristic curve.

The above control modes are exclusive; only one mode may be active at a time. The control modes' activation, deactivation, and configuration shall be field adjustable. It is the responsibility of Kahramaa to communicate to the Wind Turbine System's owner which of the above-mentioned reactive power control mode shall be activated.

4.8.2.1 Fixed Control Modes

When operated with fixed *Q* or fixed *cos φ* control mode, the Wind Turbine Unit shall control the reactive power or the *cos φ* of its output according to a set point set in the control system of the Wind Turbine System. If not explicitly specified by Kahramaa, the default setpoint values shall be 0 for fixed *Q* control mode and 1 for fixed *cos φ* control mode.

For a Wind Turbine System with a Maximum Connected Capacity greater than 11 kW, the Wind Turbine System shall also be able to receive remotely from Kahramaa control centre, the set-point following the provisions set forth in 4.9.5.

4.8.2.2 Power Related Control Mode

The Power Related Control Mode *cos φ* (*P*) controls the *cos φ* of the output as a function of the active power output. A characteristic with a minimum and maximum value and three connected lines, according to Figure 9, shall be configurable within the control systems of the Wind Turbine System; a change in active power output results in a new cos φ set point according to the characteristic.

The parameters A, B, C and D shall be field adjustable, and their settings are the responsibility of Kahramaa. If not explicitly specified by Kahramaa, these parameters shall be set as indicated below:

A $P = 0\ P_{nom}$ $\cos\varphi = 1$

B $P = 0.5\ P_{nom}$ $\cos\varphi = 1$

C $P = P_{nom}$ $\cos\varphi = 0.95$ Lag (with the Wind Turbine System absorbing reactive power from the Distribution Network)

D $P = P_{nom}$ $\cos\varphi = 0.95$ Lead (with the Wind Turbine System injecting reactive power towards the Distribution Network)

where P_{nom} is the active nominal power of the Wind Turbine Unit.

The response to a new *cos φ* set point value shall be as fast as technically feasible after the new value of the active power is reached. The accuracy of the control to each set point shall be in accordance with the requirements of 4.8.1.

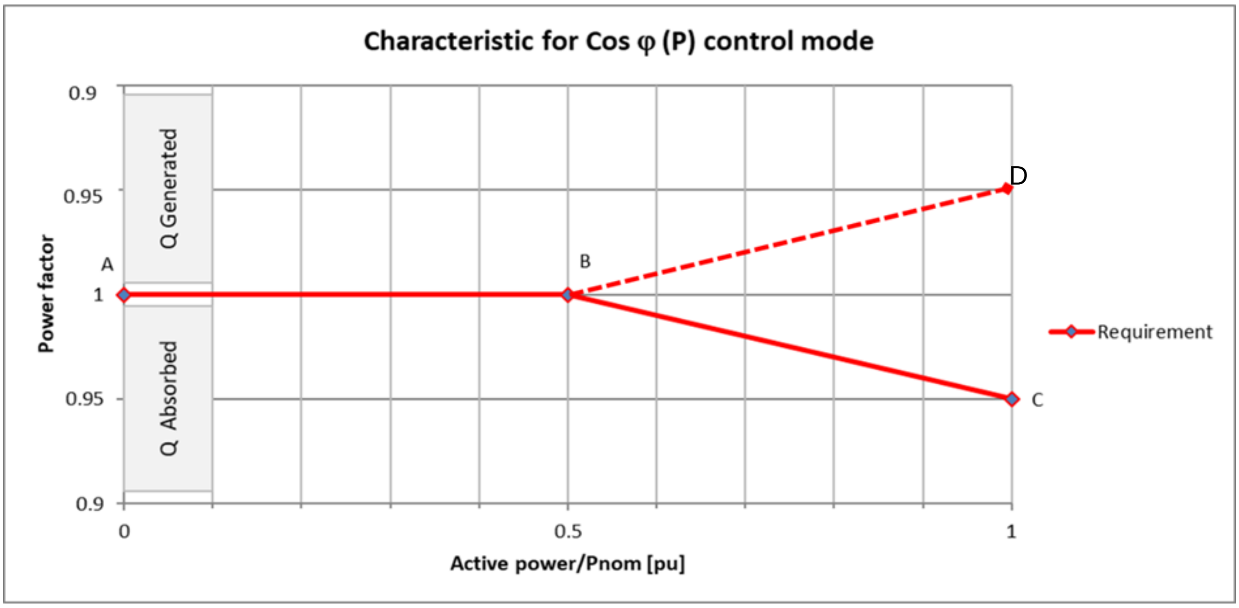


Figure 9: Characteristic for Cos φ (P) control mode

The implementation of lock-in and lock-out voltage levels should be configurable, each in the range of 90% to 110% of the nominal voltage at the Connection Point. The contribution is activated when the voltage at the Connection Point exceeds the lock-in voltage and is deactivated when the voltage drops below the lock-out voltage. When the contribution is not activated, the Wind Turbine System should be controlled with a unity power factor ($\cos \varphi = 1$).

4.8.2.3 Reactive Power Support as a Function of the Voltage Q(V)

For Wind Turbine Systems with a Maximum Connected Capacity greater than 11 kW should be able to activate this control mode, by controlling the injected reactive power in function of the grid voltage magnitude according to the diagram reported in Figure 10: define a characteristic with a minimum and maximum reactive power value and three connecting lines.

If this control mode is required from the Wind Turbine System, it is under Kahramaa responsibility communicating the configuration parameters, whose values should be determined by considering the following ranges:

- Q_{max} and $-Q_{max}$ correspond to the capability curve boundaries as per Figure 10 (e.g., 0.33 P_{nom}, where P_{nom} is the nominal power of the Wind Turbine Unit)
- $V1$ > [27<] threshold of Interface Protection
- $V4$ < [59>] threshold of Interface Protection
- $V2 < V_{nom} < V3$

Unless differently agreed with Kahramaa, the following default values can be assumed:

$V_1 = 0.9\ V_{nom}$

$V_4 = 1.1\ V_{nom}$

$V_2 = 0.95\ V_{nom}$, $V_3 = 1.05\ V_{nom}$

where V_{nom} is the nominal Voltage at the Connection Point.

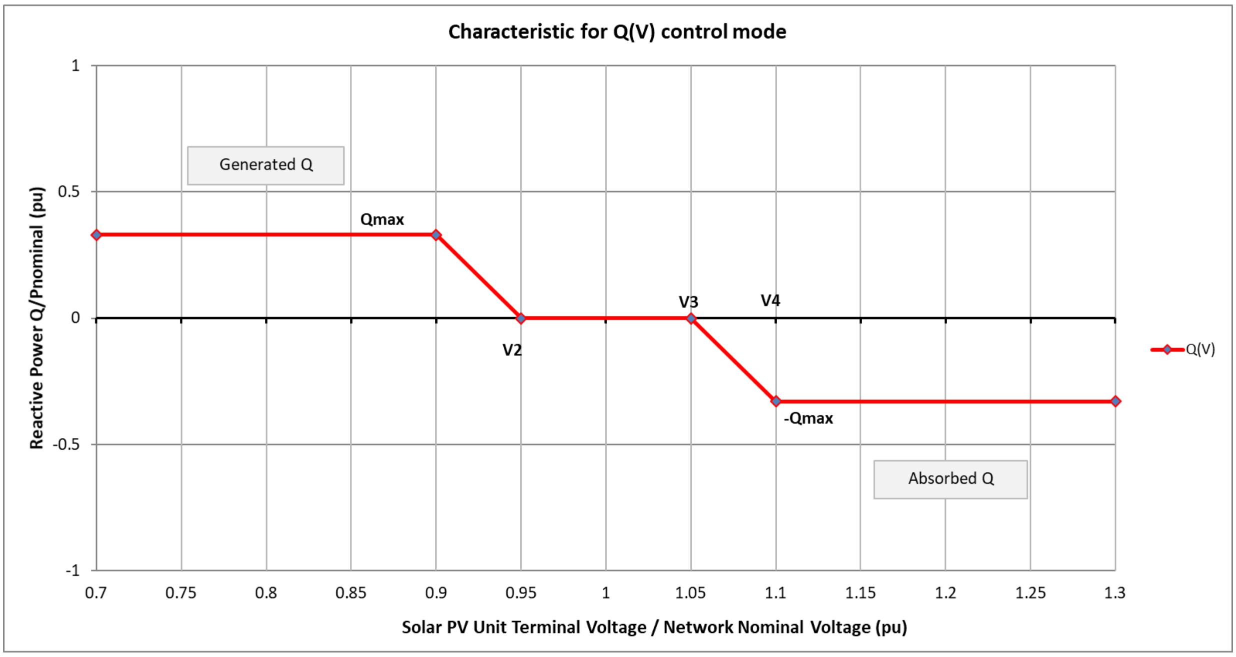


Figure 10: Characteristic for Q(V) control mode

4.8.3 Power Reduction at Increasing Voltage

In order to avoid grid disconnection due to overvoltage protection tripping, a Wind Turbine System is allowed to reduce its power output (active and/or reactive power) as a function of the rising voltage at the Connection Point. The implemented logic can be chosen by the Manufacturer/Customer. Nevertheless, the implemented logic must not induce steps or oscillations in the generated power profile.

4.9 Requirements for Power System Management

4.9.1 Connection Conditions after Programmed Disconnection

A Wind Turbine System is allowed to be connected to the Kahramaa distribution network, and to start generating electrical power when the grid voltage and frequency are within the following range for at least the observation time:

- Frequency range 49.5 Hz ≤ Frequency ≤ 50.05 Hz.
- Voltage range 90% Vnom ≤ Voltage ≤ 110% Vnom (Vnom= nominal voltage at the Connection Point).
- Minimum observation time 30s.

Synchronising a Wind Turbine System with the distribution network must be fully automatic. It should not be possible to manually close the circuit breaker between the two systems to carry out the synchronisation[5].

The synchronisation of a Wind Turbine System to the distribution network must not induce a transient variation of the voltage magnitude at the Connection Point of more than 4% of the nominal grid voltage.

[5] It means that the switch used for the synchronization with the network cannot be a manual switch.

After the connection, a Wind Turbine System should follow its target active power value with a variable rate not greater than 10% P_{nom}/min, where P_{nom} is the nominal active power of the Wind Turbine System.

The active power target should be the maximum available active power output that the Wind Turbine System can generate, taking into account the environmental conditions (e.g. wind speed), except for the operating conditions related to the provision of the grid services specified in this document (see sections 0, 4.7.3 and 4.8.3).

4.9.2 Remote Disconnection

A Wind Turbine System with a Maximum Connected Capacity greater than 100 kW must be equipped with a logic interface (input port) performing remote disconnection.

According to the provisions set forth in 4.9.5, Kahramaa have the right to specify further requirements in terms of equipment, time of execution, communication protocol and/or data to be exchanged to integrate such features into the control systems of its distribution network, allowing the remote disconnection of the Wind Turbine Systems connected to its network.

4.9.3 Automatic Reconnection after Tripping

After the trip of the Interface Protection, a Wind Turbine System is allowed to reconnect to the distribution network only if the voltage and frequency are within the following range for at least the observation time:

- Frequency range 49.5 Hz ≤ Frequency ≤ 50.05 Hz.
- Voltage range 90% V_{nom} ≤ Voltage ≤ 110% V_{nom} (V_{nom}= nominal voltage at the Connection Point).
- Minimum observation time 300s.

After reconnection, the Wind Turbine System shall return to its target active power value with a variation rate not greater than 10% P_{nom}/min, where P_{nom} is the nominal active power of the Wind Turbine System.

4.9.4 Interface Protection

The purpose of the Interface Protection is to:

a) Disconnect the Wind Turbine System from the Distribution Network in the following cases:
    - When the Distribution Network (or the feeder) where the Wind Turbine System is connected should be de-energised from the main supply source, the de-energisation can happen automatically due to protection system operation or manual/electrical disconnection. Electrical/manual disconnection in the Distribution Network can be remotely managed by Kahramaa SCADA system or by local switching.
    - The voltage and/or frequency values at the Connection Point are outside the normal operating ranges as defined in 6.5.

b) Prevent the Wind Turbine System from causing over-voltages in the distribution network when it injects active power into the grid.

c) Disconnect the Wind Turbine System from the Distribution Network in the presence of faults within the Customer power plant. In that case, the requirements for the connection of passive Customers defined in the Transmission Code should be applied.

d) Prevent damages to the Customer's equipment (generating units or loads) due to faults/incidents (e.g., short circuits) in the Distribution Network or on the Customer's installation. For such issues, the recommendations and requirements of the equipment manufacturers should be applied.

The Interface Protection must be a dedicated device that acts on the Interface Circuit Breaker. For a Wind Turbine System with a Maximum Connected Capacity smaller than or equal to 11 kW, it is allowed to integrate both the Interface Protection and the Interface Circuit Breaker into the Inverter/converting station (see, for example, the indicative scheme reported in Figure 11 , ANNEX A).

The Interface Protection should command the Interface Circuit Breaker. For a Wind Turbine System with a Maximum Connected Capacity greater than 11 kW, unless explicitly agreed by Kahramaa, only one Interface Protection and one Interface Circuit Breaker must be used.

For a Wind Turbine System with a Maximum Connected Capacity greater than 20 kW, the Interface Protection should additionally command another circuit breaker (named the Backup Circuit Breaker) with a proper delay, if the Interface Circuit Breaker fails to operate (see, for example, the indicative scheme reported in Figure 15, ANNEX A). The Backup Circuit Breaker may be a dedicated circuit breaker or an already existing circuit breaker[6]. Only manual reclosure should be possible when the Backup Circuit Breaker is triggered because the Interface Circuit Breaker has failed to open[7].

For a Wind Turbine System with a Maximum Connected Capacity greater than 11 kW, the power supply of the Interface Protection must include an uninterruptible power supply.

The loss of the auxiliary voltage on either the Interface Protection or on the control system of the Wind Turbine System should trigger the Interface Circuit Breaker without delay.

The protection functions that should be included in the Interface Protection are the following:

a) Undervoltage [27]
    - One threshold [27<] in the range [20%; 100%] of the nominal voltage at the Connection Point adjustable by steps of 5%, and delay time in the range [0.1s;100s] adjustable in steps of 0.1s.
    - One threshold [27<<] in the range [0%; 100%] of the nominal voltage at the Connection Point adjustable by steps of 5%, and delay time in the range [0.1s; 5s] adjustable in steps of 0.05s.
b) Overvoltage [59]
    - One threshold [59>] in the range [100%; 120%] of the nominal voltage at the Connection Point adjustable by steps of 1%, and delay time in the range [0.1s;100s] adjustable in steps of 0.1s.
    - One threshold [59>>] in the range [100%; 130%] of the nominal voltage at the Connection Point adjustable by steps of 1%, and delay time in the range [0.1s; 5s] adjustable in steps of 0.05s.
c) Over frequency [81>]
    - One threshold [81>] in the range [50Hz; 53Hz] adjustable by steps of 0.1Hz, and delay time in the range [0.1s; 100s] adjustable in steps of 0.1s.

[6] It is anyway recommended not to use the main switch as back-up switch since it could lead to the disconnection of the overall Customer's facility in the case the interface switch fails to open, with the consequence of the power supply also being removed to Customer's loads.

[7] The reasons are that it is required that the plant operator first acknowledges and checks the reasons why the interface switch failed to open, then remedies the technical issues and finally resumes operation.

- One threshold [81>>] in the range [50Hz; 53Hz] adjustable by steps of 0.1Hz, and delay time in the range [0.1s;5s] adjustable in steps of 0.05s.

d) Underfrequency [81<]
- One threshold [81<] in the range [47Hz; 50Hz] adjustable by steps of 0.1Hz, and delay time in the range [0.1s; 100s] adjustable in steps of 0.1s.
- One threshold [81<<] in the range [47Hz; 50Hz] adjustable by steps of 0.1Hz, and delay time in the range [0.1s; 5s] adjustable in steps of 0.05s.

e) Loss Of Mains (Anti-Islanding):

For the Loss of Mains (LOM) protection function, a wide variety of approaches can be used. Besides the passive observation of voltage and frequency, other active and passive methods are available and can be used to detect unintentional islanding. The present document does not intend to specify the method that should be used for implementing this protection function, rather than it defines specific requirements aimed at guaranteeing its reliability and effectiveness; in particular, the LOM protection must be tested according to the IEC 62116 or another equivalent standard, which provides specific procedures aimed at evaluating the performance of islanding prevention measures used with utility-interconnected Wind Turbine Systems.

The LOM protection function should allow the possibility to be excluded, and its settings should be adjustable.

The present document recognizes that it may not be straightforward for Interface Protection manufacturers to define efficient LOM protection settings for all the current and future operating conditions of Kahramaa distribution networks. This is issue is particularly complex for the most common passive methods currently deployed in specific protection devices (i.e., ROCOF and vector jump). This document also acknowledges that active methods-based LOM protection functions implemented within a Wind Turbine Generator (for example frequency shift), can be efficient under all operating conditions of the distribution network. For such reasons, it is allowed that, for a Wind Turbine System of capacity larger than 11kW, the LOM protection function can be integrated in each single Wind Turbine Generator of the system, provided that the built-in LOM protection function equipping each single Generator has been tested according to IEEE 1547.1-2005 or other equivalent standard. In these cases, and for avoiding any doubts, the under/over frequency & voltage protection functions of the interface protection should be integrated into a dedicated protective device, as stated above.

In any case, the LOM protection, irrespective of its actual position, i.e., either integrated into a dedicated Interface Protection or built-in in the Inverter/converting station, must detect island operating conditions, interrupting the Distribution Network energisation within two seconds after the island formation, unless differently specified by Kahramaa according to the MV feeder auto-reclosure time.

The protection functions for under-voltage [27] and over-voltage [59] shall be fed by all the line voltages, whereas the protection functions for under-frequency [81<] and over-frequency [81>] shall be fed by at least one line voltage.

Appropriate settings should be applied to the Interface Protection in order to ensure the correct tripping of the Wind Turbine System under specific conditions. The settings must be chosen so that, in the presence of a fault within the distribution network, the network protection systems correctly operate disconnecting the faulty feeder, and all the Wind Turbine Systems disconnect from the grid before the automatic reclosure in the MV distribution network takes place.

ANNEX B proposes default settings for 27, 59 and 81 protection functions. Such settings should be applied to the Interface Protection of a Wind Turbine System only if no other settings have been explicitly specified and communicated by Kahramaa.

Moreover, the Interface Protection should have at least two configurable digital inputs which may be used in the future[8] by Kahramaa for requesting trips, remote tripping or for implementing any other function that may be necessary to increase the hosting capacity of distributed generation while keeping proper reliability and security levels for the distribution networks.

4.9.5 Protection and Control Ranking Priority

All Wind Turbine Systems must be designed and manufactured respecting the protection and control ranking priority specified in this section. The priority ranking aims at avoiding the conflict between 2 or more functions, which could be simultaneously activated. For instance, if there is an internal fault within the Wind Turbine System, which requires the grid disconnection of the Wind Turbine System, and, at the same time, there is an under-frequency event in the network, which requires the Wind Turbine System to remain grid connected, it has to be determined which of these 2 functions should prevail over the other. According to the below priority ranking, the internal fault inside a Wind Turbine System has priority, and the disconnection must occur. The protection and control devices of a Wind Turbine System must be organised according to the following priority ranking (from highest to lowest):

1. Protection of the Wind Turbine System
2. Protection against faults within the Customer’s installation
3. Protection of the distribution network (Interface Protection)
4. Remote disconnection
5. Active power response to frequency variations
6. Remote limitation of active power
7. Remote reactive power control modes
8. Local reactive power control modes

4.9.6 Monitoring, Remote Control and Information Exchange

Continuous and reliable information sharing with the Customers connected to the Distribution Networks is a prerequisite for enabling Kahramaa to enhance the grid stability, reliability, and security. To this aim, Kahramaa deploys power system operation tools for distribution network state estimation, which require the periodic acquisition of updated information about the actual operating conditions of the Wind Turbine Systems connected to its Distribution Networks, as well as the possibility to reliably communicate with these plants in order to send proper commands aimed at implementing the grid services described in the present document.

Such requirements, which are needed in case of growing penetration level of the Wind Turbine Systems in the distribution networks, may also be also useful in supporting the implementation of smart grids functions, such as automatic network re-configuration, demand response programs, and self-healing control actions.

[8] In a scenario of growing penetration level of distributed generation in the distribution networks of the Qatar

Remote monitoring from NCC is required only for Wind Turbine Systems with a Maximum Capacity >11 kW. A Wind Turbine System with a Maximum Connected Capacity greater than 11 kW should therefore provide a bi-directional communication link for reliable data-exchange with Kahramaa. Once actually needed for distribution network operation, and according to cost/benefit assessments, Kahramaa has the right to specify additional requirements for this communication link, such as:

- Data, which shall be collected and sent to Kahramaa in real-time or periodically, related to the operating conditions of the Wind Turbine System.
- Operational instructions sent by Kahramaa that the Wind Turbine System must execute; such instructions should be compliant with the requirements indicated in the present standards (especially the requirements of 4.7.3 and 4.9.2);
- Communications architectures, technologies and protocols that can be used for supporting the above define functions.

If technically possible, Kahramaa may take advantage of already existing communication channels, such as smart metering infrastructure, to facilitate the integration of the control and monitoring activities into its ICT grid architecture, hence reducing the implementation costs. Transmission Grid Code, paragraph D.2.4.6 should apply for the communication and information exchange requirements.

4.9.7 Power Factor

Any installations containing a Wind Turbine System must comply with the power factor limits, as measured at the Connection Point, indicated in the Transmission Code.

4.9.8 Power Quality

4.9.8.1 Voltage Deviation

Under normal operating conditions, the connection and operation of a Wind Turbine System must not cause the voltage magnitude at the Customer Connection Point to vary from the system rated voltage by more than ±5% of the system rated voltage.

The allowed voltage magnitude will then range in the following intervals, as specified in the Transmission Code:

Table 3: Voltage range under normal operating conditions for the different voltage levels

Nominal Voltage	Lowest Voltage	Highest Voltage
415/240 V	394.2/228 V	435.7/252 V
11 kV	10.4 kV	11.5 kV
22 kV	20.9 kV	23.1 kV
33 kV	31.35 kV	34.65 kV

4.9.8.2 Rapid Voltage Changes

According to the recommendations of the IEC/TS 62749, connection, and disconnection of a Wind Turbine System from the distribution network must not give rise to voltage magnitude variations exceeding 3% of the system rated voltage at the Connection Point.

4.9.8.3 Harmonic and Interharmonic Voltages

According to Kahramaa Transmission Grid Code, Harmonic and interharmonic voltages at the Connection Point of a Wind Turbine System connected to the MV Distribution Network must not exceed the limits of the planning levels specified in Table 4.

Table 4: Maximum Continuous Harmonic Levels

Odd Harmonics not multiple of 3		Odd Harmonics multiple of 3		Even Harmonics	
Order h	**Harmonic voltage %**	**Order h**	**Harmonic voltage %**	**Order h**	**Harmonic voltage %**
5	5.0	3	4.0	2	2.0
7	5.0	9	2.0	4	1.0
11	3.0	15	2.0	6	0.5
13	3.0	21	2.0	8	0.5
17 ≤ h ≤ 49	1.9×17/h-0.2	21 ≤ h ≤ 45	0.2	10 ≤ h ≤ 50	0.25×10/h +0.22

NOTE: The corresponding planning level for the total harmonic distortion is THD = 3% for both 11 and 22kV voltage levels

For a Wind Turbine System connected to the LV Distribution Network, the requirements defined in IEC/TR 61000-3-15:2011 should be adopted. The requirements mentioned above concerning the voltage harmonics are fulfilled if the harmonic current emissions of the Wind Turbine System do not exceed the limits defined in the standard IEC 61000-3-12, Tables 2 and 3 (where the values with R_{sce} = 33 shall apply).

4.9.8.4 Flicker

The total flicker contribution at the Connection Point by Wind Turbine System connected to an LV and MV Distribution network must comply with the requirements defined in Table 5.

Table 5: Limit value for Flicker level

Voltage level	P_{st} (short-term flicker)	P_{lt} (long-term flicker)
≤ 1kV	0.35/0.45/0.55*	0.25/0.30/0.40*
> 1kV	0.35	0.25

* Limits apply if 4+/2/1 wind turbine system are connected to the same Connection Point

4.9.8.5 DC Injection

Wind Turbine Systems must not inject DC current into the network. The requirement is respected if the injected DC component is lower than 0.5% of the rated AC current value of the Wind Turbine System. The DC injection clause is passed when the measured DC injection of a type-tested unit is below the above threshold in all Wind Turbine Units within the Wind Turbine System.

The single Wind Turbine System must be equipped with a DC fault detection system, which disconnects the faulty unit when the above limit is exceeded. A valid alternative to such a system is an AC/AC transformer that prevents any DC injection into the network.

4.9.8.6 Clusters of Single-phase / Two-phase converter-based Wind Turbine Units

The use of three-phase inverters/converting station is required. However, for the connection of a Wind Turbine System with a Maximum Connected Capacity up to 11 kW to the LV Distribution Network, it is allowed using one or more single-phase/two-phase inverters/converting station, which should be connected either phase-to-neutral or phase-to-phase according to the LV distribution system available at the Connection Point (see ANNEX C for details). In such a case, if multiple single-phase/two-phase inverters/converting station are used, these should be equally distributed over the three phases to limit the overall power imbalance between the phases. The maximum current imbalance between the two phases must be lower than 16 A (3.84 kW at 240 Vac). Communication links between the single-phase / two-phase inverters/converting station may be used to ensure this requirement.

Any extension beyond the above-stated power limits will be possible by using three-phase inverters/converting station or by single-phase / two-phase inverters/converting station, which are connected through a communication link. In this latter case, a proper control system shall be able to re-establish the power balance between the phases and the single inverters/converting station whenever the above limit is exceeded.

4.10 Metering System

The following metering system must be installed:

1. A first smart meter (Main Meter), supplied and installed by Kahramaa at the Connection Point, in order to measure both the energy injected into the Distribution Network and consumed from this one, hence measuring the net energy at the Connection Point. For this reason, the meter must be bidirectional.
2. A second smart meter (Wind Turbine System Meter) supplied and installed by Kahramaa at the Connection Point, to measure the energy produced by only the Wind Turbine System.

The Main Meter should be installed in a location that facilitates remote communication with Kahramaa Data Centre, while the Wind Turbine System Meters should be installed within the Customer Premises, as close as possible to the Wind Turbine System.

Requirements of Transmission Grid Code, par. D.2.4.3 must apply.

4.11 Earthing and Lightning Systems

Generally, Wind Turbine Systems would not cause any variation in how earthing and lightning systems are designed. Typically for earthing systems, there are 4 different types according to BS 7671 standard, e.g., T-T systems, TN-S systems, TN-C-S systems, and TN-C systems; each of these letters indicates the system's classification. Nevertheless, a Consultant/Contractor shall ensure the correct implementation of the earthing classification case by case, and all Wind Turbine Systems connected to Kahramaa distribution network shall have the following:

- Structures, DC equipment, Inverter/converting station, AC equipment and distribution wiring shall be earthed as required.
- All metal casing/shielding of the plant shall be thoroughly grounded. In addition, the lightning arrester/masts should also be provided inside the array field.
- Equipment grounding (earthing) shall connect all non-current carrying metal receptacles, electrical boxes, and mounting structures in one long run. The grounding wire should not be switched, fused, or interrupted.
- The complete earthing system shall be electrically connected to return to earth from all equipment independent of mechanical connection.

- Earthing system design should follow the Kahramaa regulations and the standard practices.
- Earth resistance should be tested in the presence of Kahramaa's representative after earthing by a calibrated earth tester.
- A continuity test shall be executed.

For a better implementation of the requirements mentioned earlier, the Consultant / Contractor shall apply the following:

1. **Wind Turbine System DC side (when applicable)**
   - Positive and negative protected with surge arresters.
   - Common earthing grid along the whole extension shall be provided, connecting to earth all the metallic structures present in the ground, to equally potentialize the system and to avoid step and touch voltages in case of phase or earth faults from external systems or in case of induced currents/voltages during lightning strikes.
   - Metallic support structures earthed to the "common" earthing grid. This is also according to Kahramaa Electricity and Wiring Code section 3.6.

2. **Wind Turbine System AC side of the electrical system:**
   - It is like any other AC system; it shall be (in the customer's premises/boundary limit) a TN-S system for industrial installations (so PE is distributed). Obviously, for widespread unconnected customer areas, the TT system may also apply due to the TN-S system's unfeasibility.
   - The insulation transformer between the Inverter/converting station and the rest of the AC electrical system impedes the injection/transfer of phase-to-earth currents (in case of earth fault on the DC side) from the AC side to the DC side. In any case, suitable differential protection shall be provided.
   - The T-T system is only valid from Kahramaa to a single customer since Kahramaa doesn't provide an earthing conductor at such large distances. In both cases, "earth provided" and "earth not provided", the Consultant / Contractor shall refer to the Kahramaa Electricity and Wiring Code (which is valid for LV) sections 5.1 and 5.2.

The recommended practice to evaluate the need for lightning protection systems is to perform the IEC 62305 lightning risk assessment, considering the number of connected lines, the dimension of all the structures, including the relevant height, etc.

As far as the design of the lightning protection system is concerned, the Consultant / Contractor should consider the IEC 61400-24:2019 – Wind energy generation systems – Part 23: Lightning protection. Issued on July 2019, which defines the lightning environment for wind turbines and risk assessment for wind turbines in that environment, specifying technical requirements for protection of blades, other structural components and electrical and control systems against both direct and indirect effects of lightning, and describing proper test methods for validating the compliance.

Moreover, as far as earthing of the Wind Turbines is concerned, IEC 61400-24 specifies basic requirements on earthing in wind turbine systems. The earthing system of the wind turbine system must be designed to provide sufficient protection against damage due to fault currents and lightning strikes intercepted by the turbine. The design of the earthing system shall correspond to the Lightning Protection Level (LPL) for which the wind turbine protection system is designed. The earthing system shall be designed to meet four basic design requirements:

- ensure personal safety regarding the step and touch voltages which appear during earth faults and lightning current exposure.
- prevent damage to equipment.
- withstand the thermal and electrodynamic forces it will be subjected to during a fault current and lightning exposure.
- have sufficient long-term mechanical strength and corrosion resistance.

Two basic types of earth electrode arrangements that are described in IEC 62305-3 apply to wind turbines:

- Type A arrangement: This arrangement is not recommended for wind turbines but can be used for minor buildings (for example buildings containing measurement equipment or office sheds that are connected to a wind turbine farm). Type A earthing arrangements are made with horizontal or vertical electrodes connected to not less than two down conductors on the structures.
- Type B arrangement: The type B arrangement is recommended for use with wind turbines. This type of arrangement comprises either an external ring earth electrode in contact with the soil for at least 80 % of its total length or a foundation earth electrode. The ring electrodes and metal parts in the foundation shall be connected to the tower structure.

The conventional earthing impedance of the earthing system does not affect the efficiency of the air termination system and down conducting system. The earthing system shall be designed to have as low an impedance as possible to reduce the total voltage drop when conducting transient lightning currents (i.e., minimise the earth potential rise), to reduce the partial lightning current flowing into the service lines connecting the wind turbine and to reduce the risk of sparks to other service lines close to the earthing system. The party responsible for designing the foundation shall document the remedies implemented to reduce the earth potential rise when exposed to direct lightning attachment with stroke current of I rise time corresponding to LPL I. The documentation shall show how compliance with IEC 62305-3 is achieved, and how surge frequency impedances of the earthing system are considered regarding touch and step voltage, DC and transient earthing system voltage rise.

The following are minimum standards that should be followed during design and installation of earthing systems in Wind Turbine Systems.

- ANSI/IEEE 80 Guide for Safety in AC Substation Grounding
- ANSI/IEEE 81 Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System
- ANSI/IEEE 998 Guide for Direct Lightning Stroke Shielding of Substations
- ANSI/ IEEE 367 Recommended Practice for Determining the Electric Power Station Ground Potential Rise and Induced Voltage from a Power Fault

4.12 Testing and Commissioning of Wind Turbine System

Most testing and commissioning activities of Wind Turbine Systems are factory performed, whereas Installation will vary depending on type/size of wind turbine generator and site characteristics. Testing and commissioning which fucuses the connection with the distribution network is the part most relevant for Kahramaa.

So, there is defined a minimum set of parameters and details that the Contractors shall check at testing and commissioning. These parameters and details are listed in a checklist of ANNEX E.

5 Particular Requirements for LV Wind Systems

5.1 LV System characteristics

As per Electricity Wiring Code, the following characteristics of the LV electrical system in Qatar apply:

- Rated Voltage: 240/415 ± 6%, 3 Phase, 4 Wire.
- Neutral: Solidly Earthed.
- Fault Level: 31 MVA at 415 V.
- The nominal main frequency 50 Hz.
- Under normal operating conditions, there may be a variation of ± 0.1 Hz.
- Industrial conditions in the state may occasionally result in a short-term variation of ± 0.15 Hz. for a duration of only a few seconds.
- In emergency overload conditions, the frequency would be allowed to drop to 48.8 Hz, at which point load shedding would take place.
- The nominal voltage is 415/240. It is Kahramaa practice to maintain the voltage level at a value not exceeding ±6% variation from the nominal value.

5.2 DC Injection

The DC component that the Wind Turbine System injects into the network shall not exceed 0.5% of the rated AC current value of the system.

5.3 Clusters of Single-phase Wind Turbine Units

For LV connections, the use of three-phase equipment is required. Anyhow, it is allowed for a Wind Turbine System connected to the LV distribution network to be composed of clusters of single-phase Wind Turbine Units only if the sum of the currents of all the Wind Turbine Units connected to one phase does not exceed 16 A.

6 Compliance with these Technical Specifications

The Customer must ensure that its Wind Turbine System complies with the requirements defined in the present document throughout the overall lifetime of the facility.

The Customer must notify Kahramaa of any incident, failure, or planned modification of its Wind Turbine System, which may affect the compliance with the requirements defined in this document. The Customer should provide Kahramaa with all the documents, studies, and measurements useful to demonstrate the compliance of its Wind Turbine System to the requirements defined in this document.

If deemed necessary, Kahramaa shall have the right to request the Customer to carry out additional tests or studies to demonstrate the compliance of the Wind Turbine System with the provisions of the present document. Such activities may be requested during the Connection Process and throughout the lifetime of the Wind Turbine System, and more specifically, after any failures, modifications, or replacements of any equipment that may impact the System’s compliance with this document.

ANNEX A. Connection Schemes

In this document and especially in this Annex, there are several connection schemes and Single Line Diagrams, which are reported only for illustrative purposes about the possible options for designing a Wind Turbine System. These schemes aim at describing the main components needed for connecting a Wind Turbine System to the distribution network. These schemes are only indicative, and, for that reason, the Consultants should carefully assess its deployment for the specific case and user need. These schemes cannot be directly applied nor copied by the Consultant without conducting a technical assessment and a feasibility study for the Wind Turbine System they are designing.

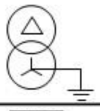
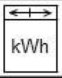
The schemes proposed in this Annex are examples of possible cases of Wind Turbine Systems connection to the LV or MV Distribution Network of Kahramaa. To summarise in single line diagrams the clauses on the connection as presented in this document, particularly in 6.2 and 4.3.

Different arrangements may be used if previously agreed with Kahramaa. These schemes have to be combined with the general scheme of the installation to feed the Customer’s loads. The cases presented in the following are listed here:

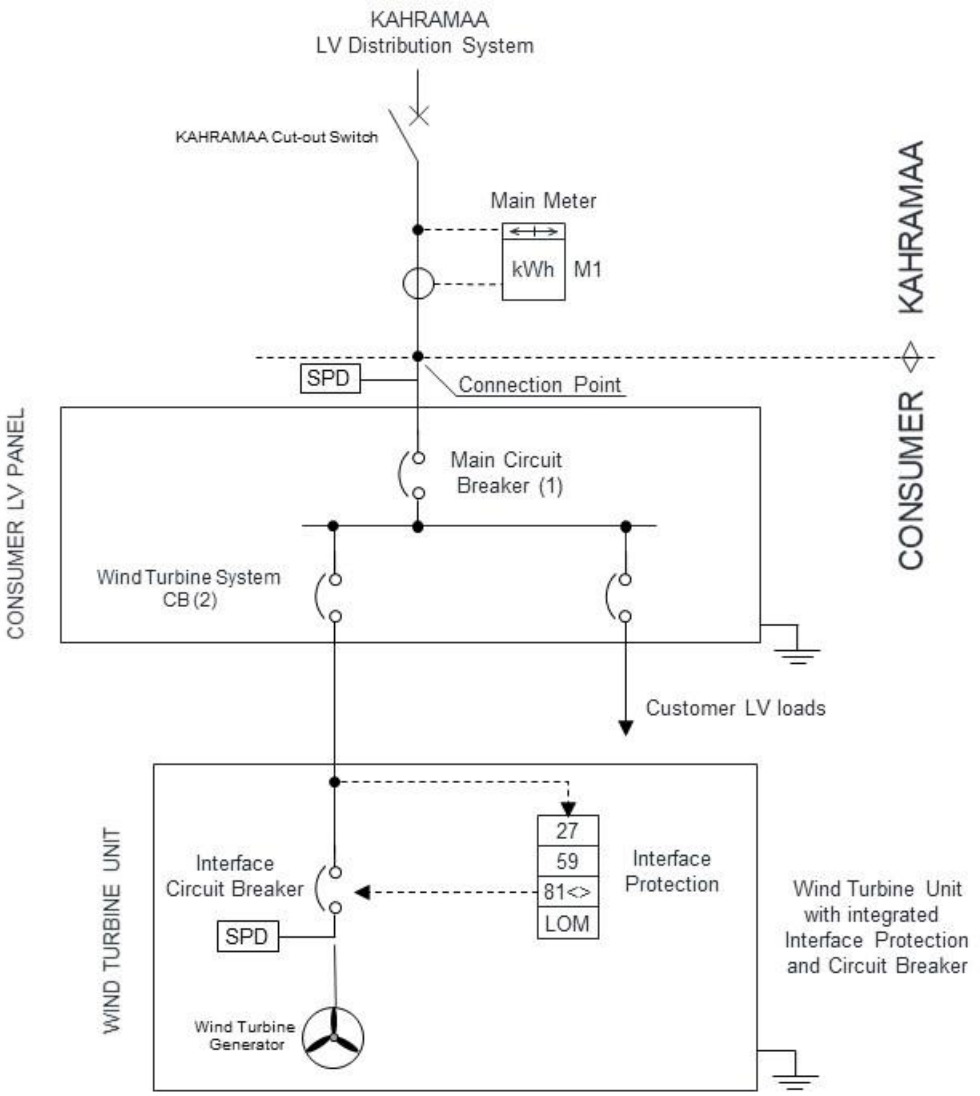
Figure	Distribution Network (LV/MV)	Maximum Connected Capacity of the Wind Turbine System	Notes
Figure 11	LV	≤ 11 KW	One three-phase Inverter/converting station (or three single-phase) with integrated Circuit Breaker and Interface Protection
Figure 12	LV	> 11 kW and ≤ 20 kW	External Interface Protection (not integrated into the Inverter/converting station)
Figure 13	LV	> 11 kW and ≤ 20 kW	Case of Figure 11 and Figure 12 where more than one Main Circuit Breaker is necessary for the absence of one general Main Circuit Breaker in the Customer’s installation
Figure 14	LV	> 11 kW and ≤ 20 kW	Multiple Wind Turbine Units with external and unique Interface Protection
Figure 15	LV	> 20 kW and ≤ 1.6 MW	Multiple Wind Turbine Units with external and unique Interface Protection. Backup Circuit Breaker is required. Wind Turbine System Meter required if Maximum Connected Capacity of the Wind Turbine System > 100 kW

Figure	Distribution Network (LV/MV)	Maximum Connected Capacity of the Wind Turbine System	Notes
Figure 16	MV	≥ 100 kW and ≤ 1.6 MW	Multiple Wind Turbine Units with external and unique Interface Protection. Interface Protection on the LV side. Backup Circuit Breaker is required. Wind Turbine System Meter required if Maximum Connected Capacity of the Wind Turbine System > 100 kW
Figure 17	MV	≥ 100 kW and ≤ 25 MW	Multiple Wind Turbine Units with external and unique Interface Protection. Interface Protection on the MV side. Backup Circuit Breaker required. Wind Turbine System Meter required if Maximum Connected Capacity of the Wind Turbine System > 100 kW

The meaning of the symbols used in the single line diagrams is explained hereinafter:

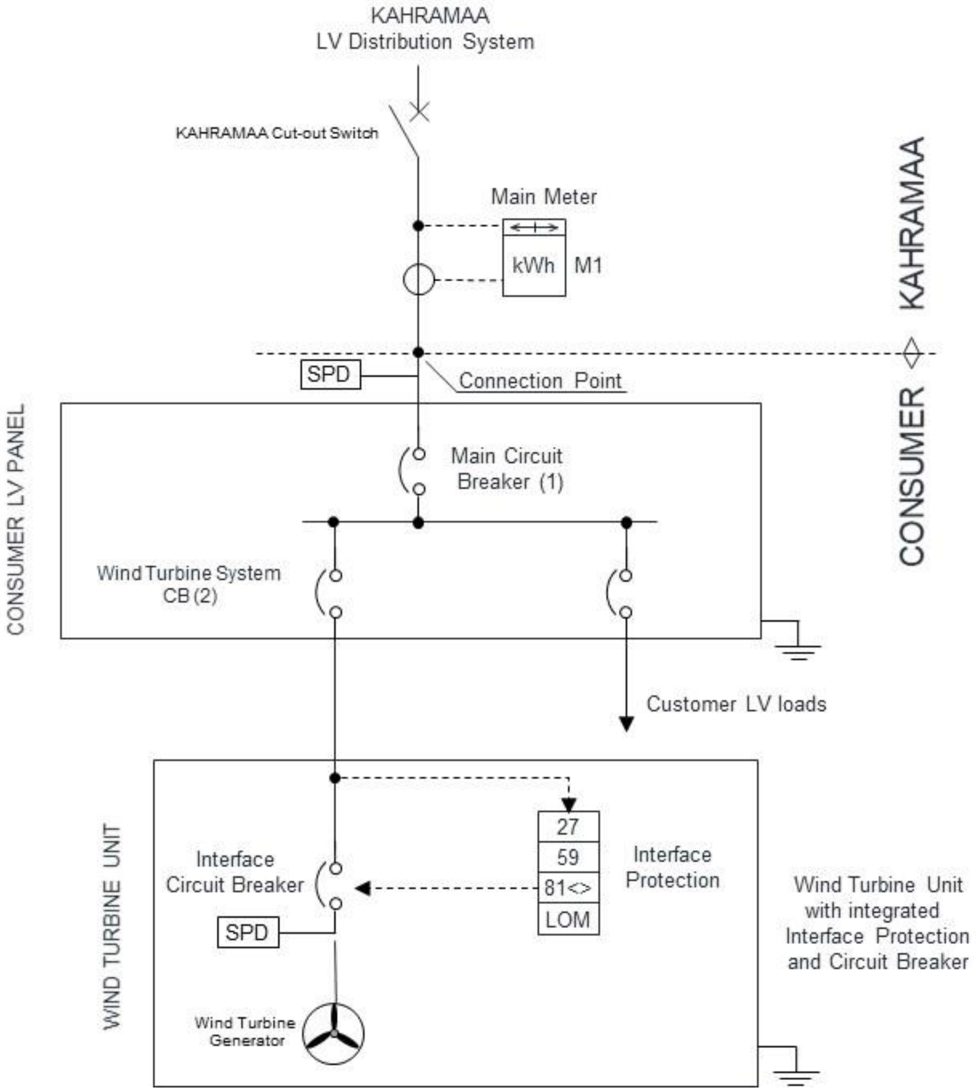
LEGEND	
	CIRCUIT BREAKER
	SWITCH
	CURRENT TRANSFORMER (CT)
	POTENTIAL TRANSFORMER (PT)
	LOAD
	INVERTER
	POWER TRANSFORMER
	BI-DIRECTIONAL ENERGY SMART METER (4 QUADRANTS)
	WIND TURBINE GENERATOR

ANSI CODES FOR PROTECTIONS	
27	UNDERVOLTAGE PROTECTION
59	OVERVOLTAGE PROTECTION
81	UNDERFREQUENCY (81<) PROTECTION OVERFREQUENCY (81>) PROTECTION
LOM	LOSS OF MAINS PROTECTION
50	INSTANTANEOUS OVERCURRENT PROTECTION
51	IDMTL OVERCURRENT PROTECTION
50N/51N	EARTH FAULT CURRENT PROTECTION



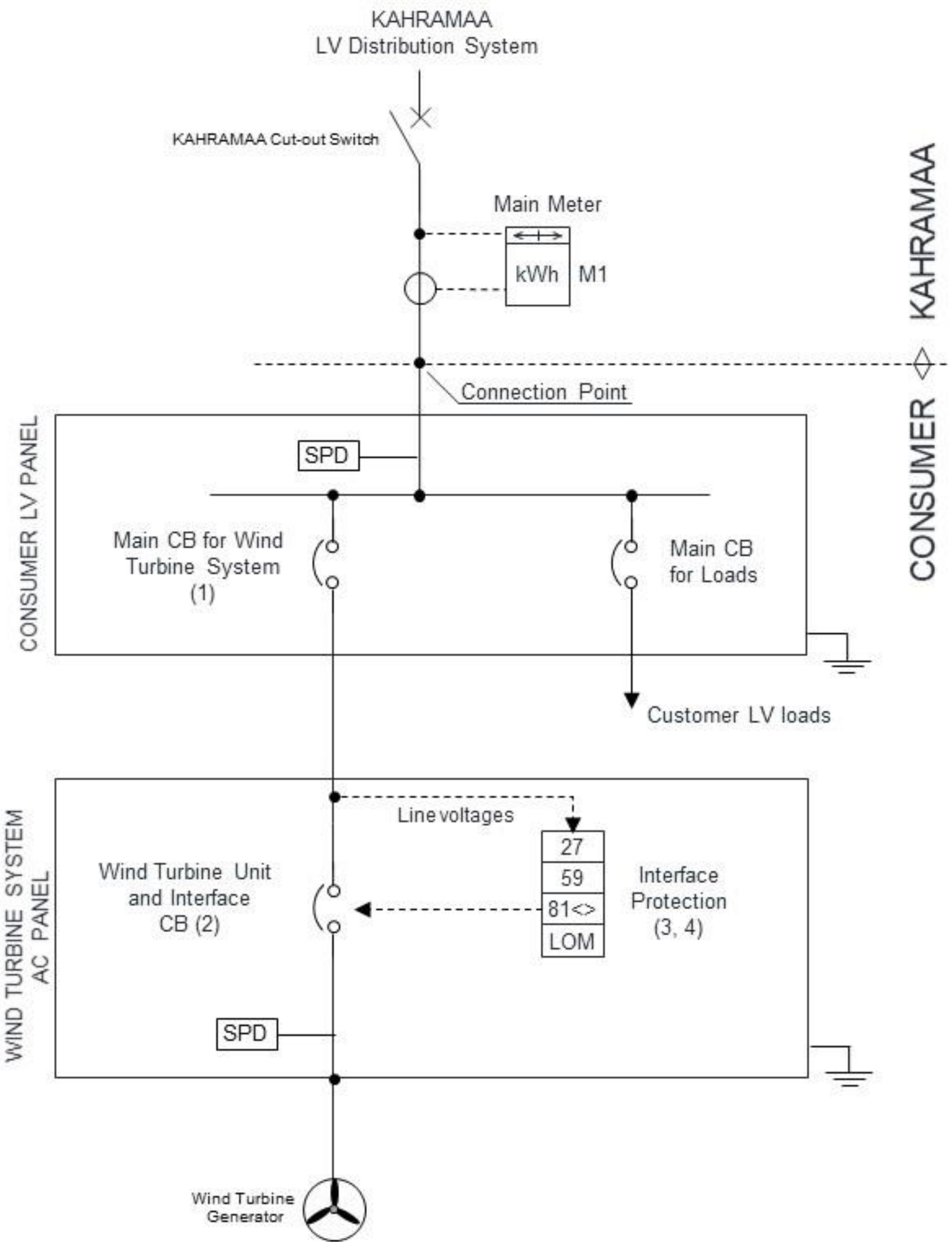
NOTES:
(1) Automatic Circuit Breaker
(2) Automatic Circuit Breaker with:
- Overload Protection
- Short Circuit Protection
- Protection against electric shock (RCD)

Figure 11: Indicative Scheme for LV Connection – Wind Turbine System with Maximum Connected Capacity ≤ 11 kW



NOTES:
(1) Automatic Circuit Breaker
(2) Motorized Automatic Circuit Breaker
(3) LOM protection is not required if it is integrated in the WTG
(4) Auxiliary power supply from a UPS

Figure 12: Indicative Scheme for LV Connection – Wind Turbine System with Maximum Connected Capacity > 11 kW and ≤ 20 kW – External Interface Protection



NOTES:

(1) Automatic Circuit Breaker with:

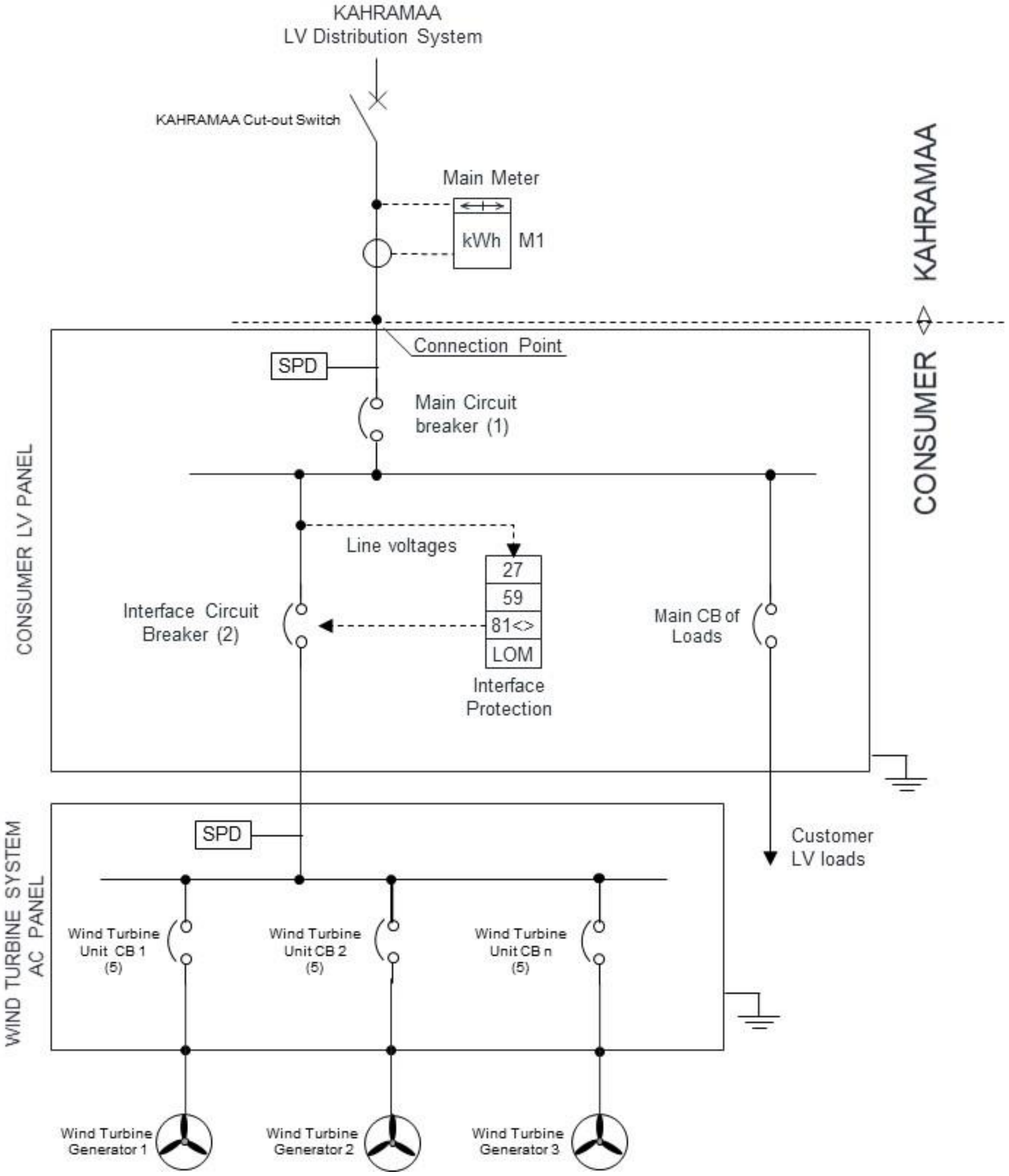
- Overload Protection
- Short Circuit Protection
- Protection against electric shock (RCD)

(2) Motorized Automatic Circuit Breaker.

(3) LOM protection is not required if it is integrated in the WTG

(4) Auxiliary power supply from a UPS

Figure 13: Indicative Scheme for LV Connection – Case of Two (or more) Main Circuit Breakers in absence of one general Main Circuit Breaker in the incomer from Kahramaa (case as per Figure 11 shown, but this applies to both schemes of Figure 11 and Figure 12)

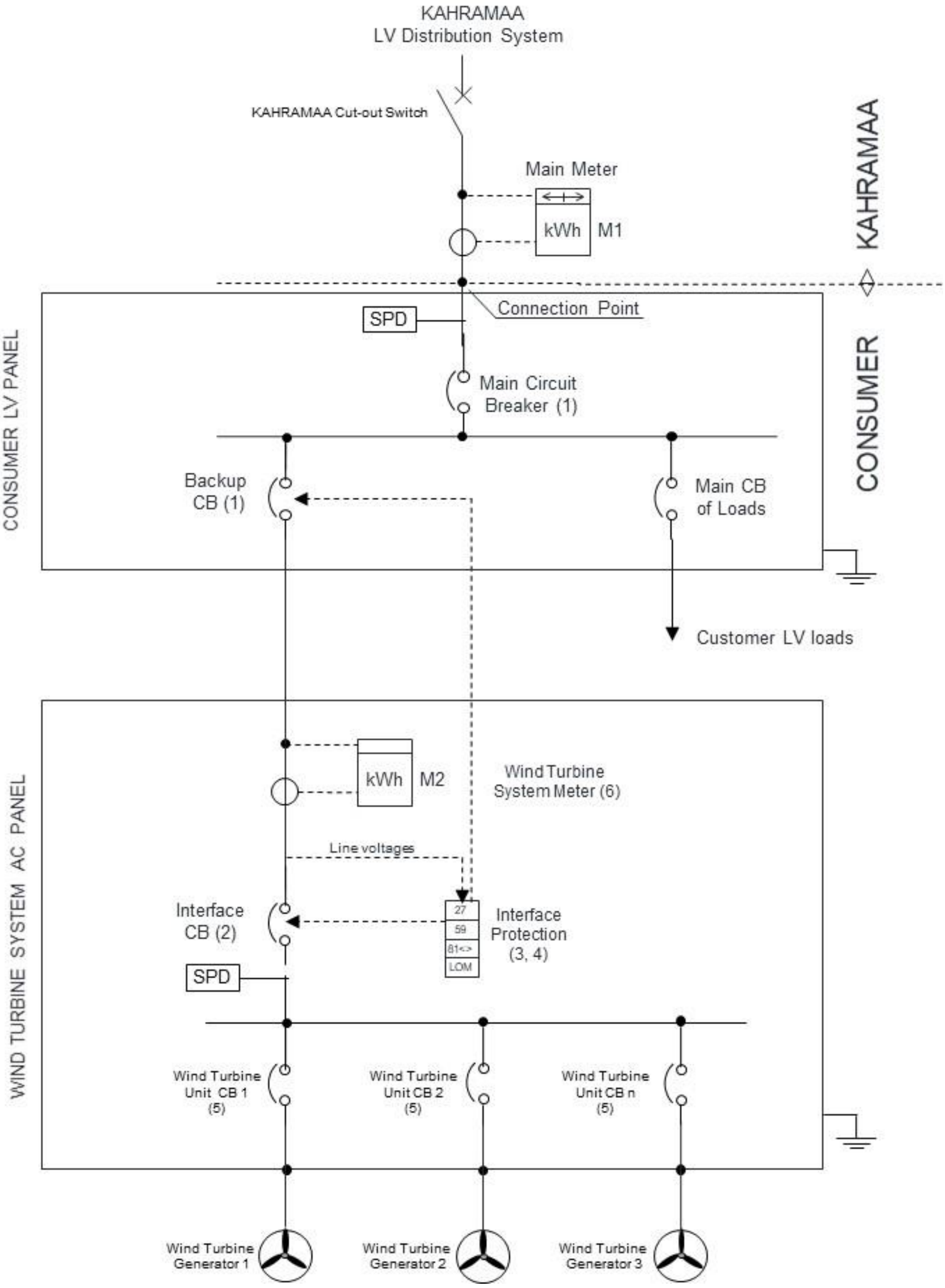


NOTES:

(1) Automatic Circuit Breaker
(2) Motorized Automatic Circuit Breaker with:
- Overload Protection
- Short Circuit Protection
- Protection against electric shock (RCD)

(3) LOM protection is not required if it is integrated in each WTG
(4) Auxiliary power supply from a UPS
(5) Automatic Circuit Breaker

Figure 14: Indicative Scheme for LV Connection – Wind Turbine System with Maximum Connected Capacity > 11 kW and ≤ 20 kW – Multiple Wind Turbine Units with external and unique Interface Protection



NOTES:

(1) Automatic Circuit Breaker with: Overload Protection, Short Circuit Protection against electric shock (RCD)
(2) Motorized Automatic Circuit Breaker
(3) LOM protection is not required if integrated in each WTG
(4) Auxiliary power supply from a UPS
(5) Automatic Circuit Breaker
(6) Second meter to be supplied by Kahramaa for Pnom > 100 kW

Figure 15: Indicative Scheme for LV Connection – Wind Turbine System with Maximum Connected Capacity > 20 kW and ≤ 1.6 MW – Multiple Wind Turbine Units with external and unique Interface Protection; Backup Circuit Breaker; Wind Turbine System Meter (only if Nominal Power of the Wind Turbine System > 100 kW)

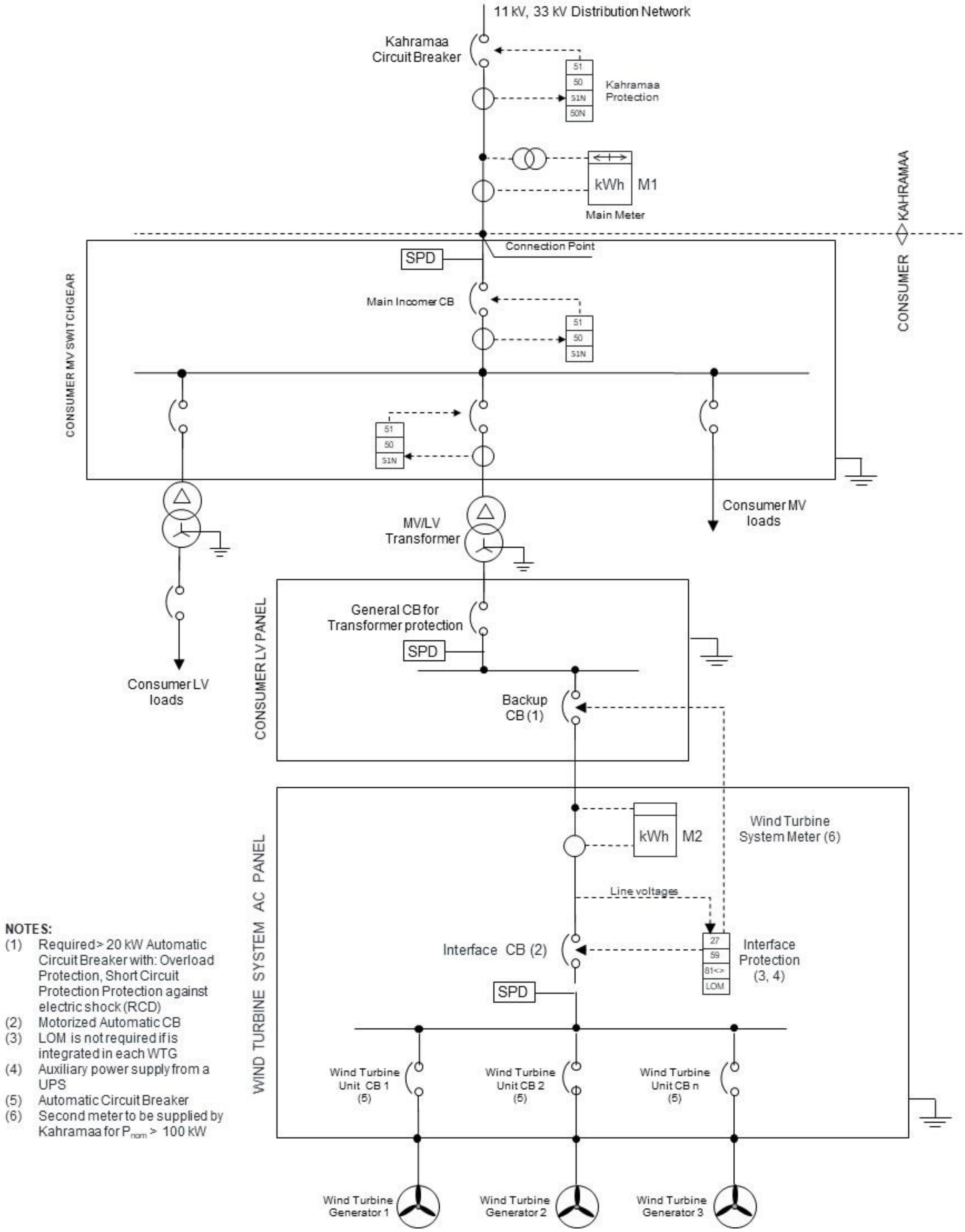
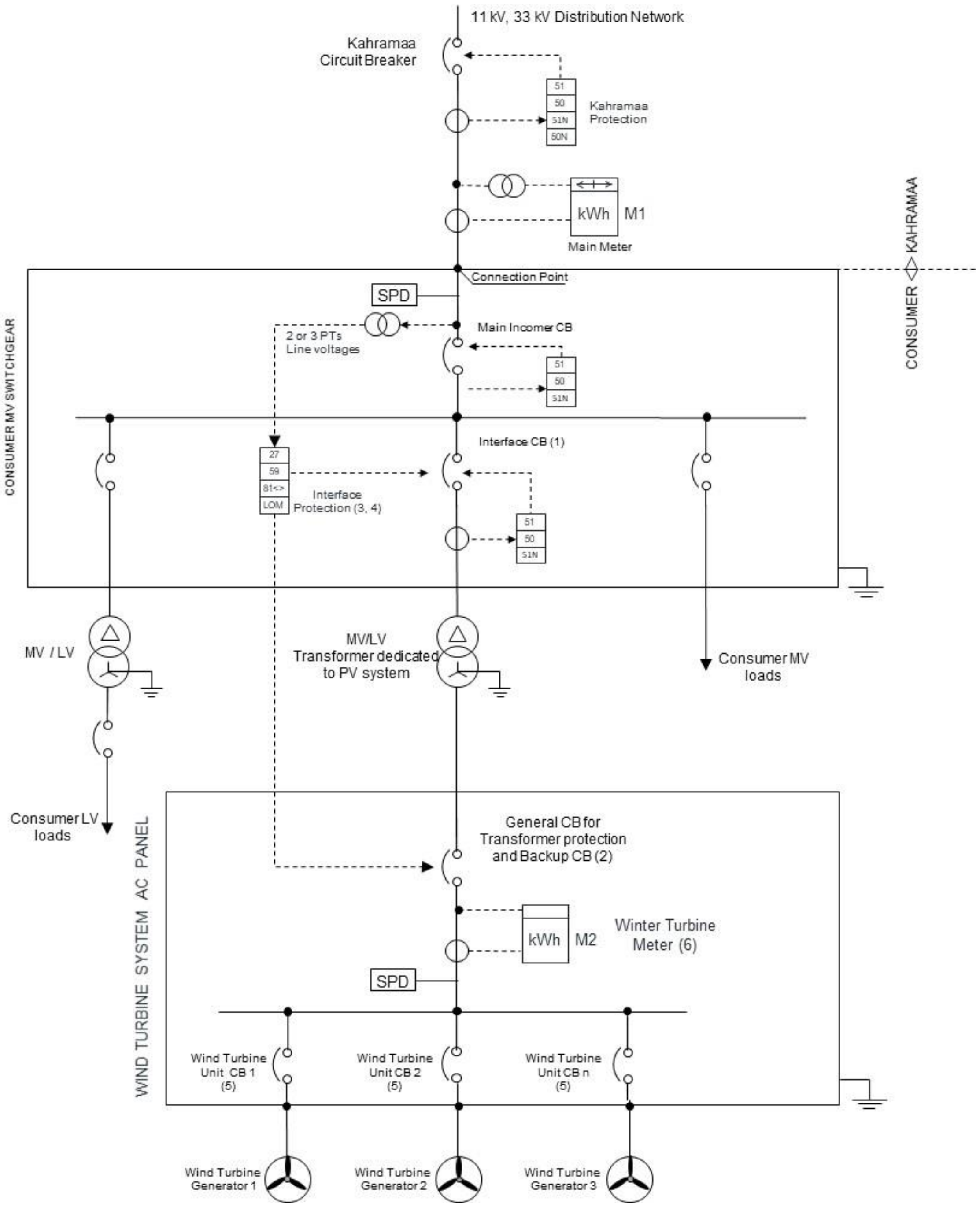


Figure 16: Indicative Scheme for MV Connection - Interface Protection on the LV side Wind Turbine System with Maximum Connected Capacity > 100 kW – Multiple Wind Turbine Units with external and unique Interface Protection on the LV side; Backup Circuit Breaker; Wind Turbine System Meter (only if Nominal Power of the Wind Turbine System > 100 kW)



NOTES:

(1) Motorized Automatic Circuit Breaker with Overload Protection (51), Phase Protection (50), Earth Protection (51N)
(2) Automatic Circuit Breaker with Overload Protection, Short Circuit Protection against electric shock (RCD)
(3) LOM is not required if integrated in each Wind Turbine Generator
(4) Auxiliary power supply from a UPS
(5) Automatic Circuit Breaker
(6) Second meter to be supplied by Kahramaa for Pnom > 100 kW

Figure 17: Indicative Scheme for MV Connection– Interface Protection on the MV side Wind Turbine System with Maximum Connected Capacity > 100 kW – Multiple Wind Turbine Units with external and unique Interface Protection on the MV side; Backup Circuit Breaker; Wind Turbine System Meter (only if Maximum Connected Capacity of the Wind Turbine System > 100 kW)

ANNEX B. Default Settings of Interface Protection

The following table reports the default settings to be implemented in the Interface Protection of Wind Turbine Systems when Kahramaa has communicated no other settings.

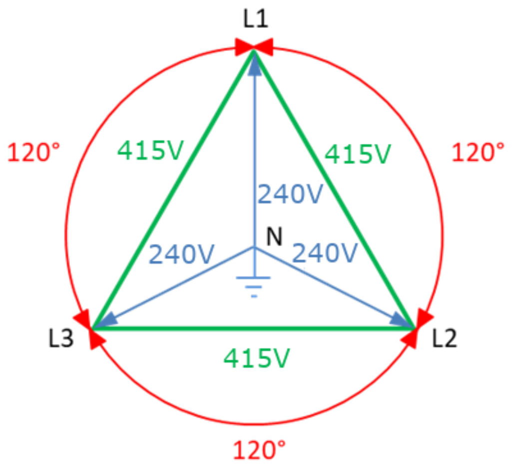
Table 6: Default settings for the protection functions of the IP

Protection function	Settings	
	Threshold	Time delay
27<	90% Nominal Voltage	3 s
27<<	40% Nominal Voltage	1.5 s
59>	110% Nominal Voltage	3 s
59>>	120% Nominal Voltage	0.2 s
81>>	52.5 Hz	0.1 s
81<	47.5 Hz	4 s
81<<	47 Hz	0.1 s

NOTE: in case the Interface Protection is external, the built-in IP can either be excluded (if LOM is made externally) or configured with higher settings

ANNEX C. Configuration of LV Distribution Systems of Kahramaa

Three-phase four wires 415/240 Vac configuration



ANNEX D. Service and Environmental Conditions

As per Electricity Wiring Code, par. 1.3.1, Qatar experiences a tropical climate and generally the ground area is at sea level. The climate in Qatar in the summer months is hot and humid and a humidity of 100% at 30°C has been recorded and seem to be as following data:

1. The Maximum sun radiation temperature in summer - 84°C.
2. The Maximum ambient temperature in summer - 52°C.
3. The Average max. Ambient temperature in summer - 45°C.
4. The Minimum ambient temperature in winter - 0°C.
5. The maximum ground temperature is 30°C at a depth of 1 meter.
6. The maximum seawater temperature is 40°C with a maximum tidal variation of approximately 2.40 meters.
7. Atmosphere is salt laden and very corrosive.
8. The prevailing winds are northerly and gales with gusts approaching 140 KPH have been recorded accompanied by a high level of dust in the air.
9. The mean and maximum Relative Humidity during the summer month of April to September inclusive are as follows at the associated temperatures given:

Table 7: mean and maximum Relative Humidity

Mean % RH	
°C	% R.H.
27	72
32	61
38	48
43	30

Maximum % RH	
°C	% R.H.
27	97
33	87
39	84
44	51

10. The average annual rainfall is 50 mm and generally falls between January and April inclusive.

As per Electricity Wiring Code, Appendix No. 02, the service electrical cabinets will be used in the following climatic conditions:

- Maximum Direct Sunlight Temperature: 75°C
- Maximum Ambient Air Temperature: 50°C
- Maximum Relative Humidity: 100%
- Occasional sandstorms with height salt content.
- Occasional fog mixed with salty sea water mist.
- Occasional torrential rain in winter and up to 15 cm per year.
- Prolonged periods with temperatures between 30oC and 50oC with humidity simultaneously between 30% and 100%.

As per Electricity Wiring Code, paragraph 10.8, all windings shall be tropically impregnated and be designed for operations in a very dusty environment with an ambient of 50° C and of and humidity 80%.

Table 8: Parameters of Environmental Conditions

Parameter	Value
Altitude above mean sea level (msl):	a. up to 1000m (normal) b. above 1000m (as required)

Parameter	Value
Ambient Temperature (Outdoor):	Minimum: -5 °C Maximum: 55 °C Monthly average of the hottest month: 40 °C Yearly average: 30 °C Design temperature: 50 °C [as per Wiring code par. 10.8]
Ambient Temperature (Indoor):	Air-conditioned buildings: 25 °C Buildings where no air-conditioning is provided: 40 °C
Ambient ground temperature:	40 °C
Maximum relative humidity:	100% [80% as per Wiring code par. 10.8]
Temperature of exposed surfaces due to solar radiation:	75 °C
Soil thermal resistivity one (1) meter and below:	2.0 °C.m/W
Maximum earthquake frequency / severity:	Zone 2 (US Build Code)
Soil condition– General:	Corrosive. Widespread salt deposits.
Ground water table level:	Varies from deep to very near the surface
Soil pH:	7.0 – 8.5
Salt concentrations (typical) Sulphates (SO3), by weight: 0 – 10 % Chlorides (as NaCl), by weight:	0 - 5%
Contamination level: Equivalent Salt Deposit Density (ESDD) in a period of any six:	0.3 to 0.5 mg/cm^2
Average hydrogen sulphide in the atmosphere:	40 Mg/m^3 (0.03 ppm)
Soil salinity:	0 to 140 g/m^3 (0 to 100000 ppm)
Average rainfall per year:	150 mm
Maximum wind velocity:	150 km/h
Approximate highest density solar radiation average over the summer months	1000 W/m^2
Isokeraunic level: (average / maximum / above 1000m):	10 /15 / 50 storm days/year

1) All equipment/material and accessories shall be designed for satisfactory operation/performance based on the above (Indoor or Outdoor or Ground) service conditions.
2) All outdoor equipment enclosures/material shall be weatherproof, all metal parts shall be corrosion and/or abrasion resistant, and the degree of protection shall be at least IP54 as per IEC 60529. The degree of protection for all indoor equipment shall be IP41 as per IEC 60529.

ANNEX E. Testing and Commissioning

E.1 Scope

This Annex describes the Testing and Commissioning activities to be performed at the end of the construction of a Wind Turbine System, to connect to the Distribution Network of Kahramaa. Kahramaa will inspect the site and witness the commissioning tests. Kahramaa will check the commissioning report following the checklist of Annex G.

E.2 References

As for:

- Companion documents
- Reference documents
- Terms and definitions

the contractor shall refer to the parent document (Technical Specifications).

E.3 Inspection Application

The Contractor that applies for “REG Inspection and Notification Commissioning Test” according to the Connection Process, states that the construction termination and that the Wind system is ready for inspection. As a minimum the Contractor shall provide to Kahramaa with the information and documents specified in Table 1 of Annex G.

Kahramaa should check and revise the documents. If satisfied, Kahramaa will coordinate with the Contractor to fix date/time to conduct the on-site inspection.

E.4 On-Site Inspection

The on-site inspection and witness made by Kahramaa will focus protections and components that may impact the distribution network.

E.5 Commissioning Report

Once commissioning is completed, the Contractor will provide a “REG Commissioning Test Report“, presenting and detailing all test results. Kahramaa will review the Commissioning report following the checklist of Table 2 of Annex G.

E.6 Witnessing the Commissioning

Kahramaa may witness the commissioning tests on-site, subject to his will, evaluation and needs. When on site for commissioning, Kahramaa may request the Contractor to perform additional tests as deemed necessary.

The Commissioning Report Evaluation checklist is in Table 3 of Annex G.

ANNEX F. Wind Turbines’ Corrosion Standards

Regarding the design of the Wind Turbine System, which is not the scope of this document are included as request. The corrosion protection systems are required to protect the steel construction against corrosion phenomena during their service life, such as uniform corrosion, pitting corrosion, crevice corrosion, galvanic corrosion, and erosion corrosion, which could compromise the long-term stability of the steel structures, especially in harsh marine environment.

Corrosion protection systems should comply with technical requirements defined by national and international standards, and national regulations, which aim at assuring assure the deployment of the best available techniques.

The following references are some examples of applicable standards:

- DIN 81249-2 Corrosion of Metals in Sea Water and Sea Atmosphere - Part 2: Free Corrosion in Sea Water German Institute for Standardisation (Deutsches Institut für Normung) (2013), p. 63
- DNVGL-RP-0416 Corrosion Protection for Wind Turbines, RP-0416
- DNVGL-RP-B401 Corrosion protection design RP-B401 (2017)
- NORSOK Standard M-501 Surface Preparation and Protective Coating (Edition 6) (2012), February 2012
- VGB-S-021-01-2018-04-EN, VGB/BAW-Standard Corrosion Protection for Offshore Wind Structures Part 1: General
- VGB-S-021-02-2018-04-EN, VGB/BAW-Standard Corrosion protection for offshore wind structures - Part 2: Requirements for Corrosion Protection Systems
- VGB-S-021-03-2018-04-EN, VGB/BAW-Standard Corrosion Protection for Offshore Wind Structures - Part3: Application of Coating Systems

ANNEX G. Check List for Commessioning a wind Turbine System

Description

This Form contains the checklists to be filled for verify the testing and commissioning of a Wind Turbine System.

Table 9: Inspection Application Checklist

Data name	Data type	Author	Notes
Contractor			
Contractor name	Alphabetic	Contractor	
Documents and Request of Inspection			
1. Declaration of Conformity (letter of undertaking from Contractor)	File	Consultant / Contractor	
2. Protection arrangement and settings, including: • Overcurrent setting • short-circuit ratings of the installed equipment • Interface Protection settings	File	Consultant/ Contractor	Interface protection settings to include: - Under voltage [27] - Over voltage [59] - Over frequency [81>] - Under frequency [81<] - LOM (Anti-Islanding)
3. Electrical Diagram, data sheets and SLDs of Equipment at Connection Point	File	Consultant/ Contractor	Including installed equipment certifications
4. Operation manual and maintenance manual	File	Consultant/ Contractor	
5. Site test report after successful completion of all relevant tests. • Test on towers (dimensional inspection, coating, non-destructive reports, etc.) • Electrical components (generator, transformer, converter system, etc.) • Mechanical components (gearbox, yaw and pitch systems, etc.) • Controller test	File	Consultant/ Contractor	

Table 10: Onsite Inspection Checklist

Data name	Data type	Filled by	Notes
AC System - General			
The Main Circuit Breaker is present*	Selection	Kahramaa	• Yes • No Notes:
The Interface Circuit Breaker is present*	Selection	Kahramaa	• Yes • No Notes:
Interface protection (IP) is present*	Selection	Kahramaa	• Yes • No Notes:
The Backup interface device is present*	Selection	Kahramaa	• Yes • No • Not Applicable Notes:
An UPS to support the Interface protection system is present*	Selection	Kahramaa	• Yes • No Notes:
Wind turbine number plats to check the installed capacity is correct*	Selection	Kahramaa	• Yes • No Notes:
Monitoring system is present*	Selection	Kahramaa	• Yes • No • Not Applicable Notes:
Labelling and identification			
Dual supply warning labels are fitted at point of interconnection*	Selection	Kahramaa	• Yes • No Notes:
A single line wiring diagram is displayed in the electrical room*	Selection	Kahramaa	• Yes • No Notes:
Contractors, O&M team, fire fighters and concerned persons details are displayed in the electrical room including their phone numbers and hotline numbers*	Selection	Kahramaa	• Yes • No Notes:
All signs and labels in the electrical room are suitably affixed and durable*	Selection	Kahramaa	• Yes • No Notes:
All signs and labels in the electrical room are in both Arabic and English*	Selection	Kahramaa	• Yes • No Notes:
Site Plan			
Simplified site plan with position of wind turbines, cables, and disconnectors exposed close to main energy meter, and close to the manual call point (if present)	Selection	Kahramaa	• Yes • No • Not Applicable Notes:
Final Approval			

Data name	Data type	Filled by	Notes
Is the Inspection approved?	Selection	Kahramaa	☐ **Yes** ☐ **No** Notes:
Will Kahramaa witness the commissioning test?	Selection	Kahramaa	• Yes • No Notes:
Name of the Kahramaa Inspector	Alphabetic	Kahramaa	

Table 11: Commissioning Report Evaluation

Data name	Data type	Filled by	Notes
REG System – General			
Expected date of energization	Numeric	Kahramaa	Automatically provided
Commissioning Test Report including: - Test Report of the Interface Protection including: • 27< 90% Nominal Voltage test • 27<< 40% Nominal Voltage test • 59> 110% Nominal Voltage test • 59>> 120% Nominal Voltage test • 81>> over frequency test 52.5 Hz • 81< under frequency test 47.5Hz • 81<< under frequency test 47 Hz - Performance test - Power Quality test	File	Kahramaa	• Yes • No Notes:
Responsible of the Commissioning (on Applicant's side)			
Name of the Responsible	Alphabetic	Kahramaa	
Other Subjects involved	Alphabetic	Kahramaa	Names and Roles
Interface Protection			
Functions of Interface Protection as per Technical Specifications	Selection	Kahramaa	• Yes • No Notes:
Thresholds as per Technical Specifications • 27< 90% Nominal Voltage • 27<< 40% Nominal Voltage • 59> 110% Nominal Voltage • 59>> 120% Nominal Voltage • 81>> over frequency 52.5 Hz • 81< under frequency 47.5 Hz • 81<< under frequency 47 Hz	Selection	Kahramaa	• Yes • No Notes:
Times of intervention of Interface Protection as per Technical Specifications • 27< 90% Nominal Voltage 3.0 s • 27<< 40% Nominal Voltage 1.5 s • 59> 110% Nominal Voltage 3.0 s • 59>> 120% Nominal Voltage 0.2 s • 81>> 52.5 Hz 0.1 s • 81< 47.5 Hz 4 s • 81<<47 Hz 0.1 s	Selection	Kahramaa	• Yes • No Notes:
Interface device circuit breakers off in case of a power failure	Selection	Kahramaa	• Yes • No Notes:

Data name	Data type	Filled by	Notes
Interface Protection recloses Interface Device after power recovery	Selection	Kahramaa	• Yes • No Notes:
Final Approval			
Consumer Commissioning Report approved?	Selection	Kahramaa	□ **Yes** □ **No** **Notes:**
Name of the Kahramaa Inspector	Alphabetic	Kahramaa	