

PV Large Scale Technical Connection Standards

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1 SCOPE

This document provides a common set of requirements for Large Scale Solar PV (Photovoltaic) Systems exceeding 2 MW which intend to operate in parallel with the LV & MV distribution networks of Saudi Electricity Company (SEC) in the Kingdom of Saudi Arabia (KSA). These requirements shall be fulfilled regardless the presence of loads in the Consumer's installation.

Most of the technical requirements introduced for Small Scale PV Systems are extendable for the Large-Scale PV Systems, and as a consequence, many requirements for connecting Large-Scale PV systems wouldn't change. In this document the requirements categorized as follow:

- Requirements for the equipment to be used for the connection of Large-Scale PV System with the distribution network.
- Requirements to support the frequency and voltage stability of the power system when it is subject to disturbances.
- Requirements for the start-up, the operation and the disconnection of Large-Scale PV Systems.
- Requirements to prevent the Large-Scale PV Systems from causing disturbances and damages either to the distribution network and to the other Consumers connected to the same distribution network.
- Requirements to prevent the Large-Scale PV Systems from operating in parallel with a portion of the distribution network which has been disconnected on purpose from the main power system.

The present document is not in contradiction with additional requirements set out by other national & international standards, network codes or specific technical requirements of SEC, and which may apply for the connection of Large-Scale PV System.
In particular, these are:

- WERA Regulatory Framework for Renewable Energy Generation RF-REG (in this document referred to as "WERA Regulations"), and
- The Saudi Arabian Distribution Code Updated Version: April 2021 (in this document referred to as "Distribution Code").

The Distribution Code is applicable to all users of the distribution system and still represents the main technical document to refer to for the connection of a new Consumer or for the modification of the connection of an existing Consumer. The present Technical Standards shall apply in case the new installation (or the modified one) includes a Large Scale PV Systems as defined in WERA Regulations and shall be intended as an extension of the Distribution Code for what not directly ruled by the code itself. For all the aspects not covered by the present document, reference shall be made to the Distribution Code.

It is not within the scope of the present document to:

- define the process to be followed for the selection and evaluation of the Exit Point.
- define the process to be followed for the assessment of the impact of connecting Large Scale PV Systems to SEC distribution network.
- define the process to be followed for the assessment of a connection application and its compliance with the present standards.

This information can be found in other companion documents, as listed in chapter 0.
Finally, it is not under the purpose of these standards to define technical rules for the off-grid operation of networks in isolated (e.g. rural) areas, where no part of SEC distribution network is involved.
Unless otherwise explicitly specified, the requirements set forth by the present standards apply to new Large Scale PV Systems, i.e. to those Large Scale PV Systems which do not have already been approved by SEC at the date of publication of the standards.

Finally, even if it is not directly within the scope of the present standards, it is important to stress and remind the fundamental importance and necessity for these systems to be built in a workmanlike manner, which means the use of products and their assembly in accordance with the national and international standards commonly used for the planning, design, installation, operation and maintenance of Solar PV Systems in general.
As regards the Service Conditions, the equipment/material used for Large Scale PV Systems shall be suitable for operating at their standard ratings under the usual service condition in the inland, desert or coastal areas environment in the Kingdom of Saudi Arabia. Applicable standards for KSA are indicated in ANNEX C.

1.1 Notice to users

This document is for use of employees of SEC, Consumers, Consultants, Contractors and Manufacturers. Users of this guideline should consult all applicable laws and regulations. Users are responsible for observing or referring to the applicable regulatory requirements. SEC does not, by the publication of its standards, 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. These Technical Standards at any point in time consist of the current edition of the document together with any amendments, corrigenda, or errata then in effect. All users should ensure that they have the latest edition of this document, uploaded on SEC website.

Finally, the user shall refer to Saudi Building Code – Section 401 - Chapter 712, as well as to applicable SASO Standards or International Standards mentioned in these SEC documents, unless differently indicated in other SEC documents related to Solar PV Systems Regulations.

1.2 SEC Limitation of Liability and Consumer's undertaking

SEC 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 Exit point. Consumers are responsible for observing or referring to the applicable laws and regulatory requirements.

It is the responsibility of the Consumer to determine that the connection equipment's specifications and confirmed performance satisfy the technical needs of the SEC system and to be compatible with the present and any other applicable SEC standards. SEC standards are indispensable for the solar PV application. All equipment in an installation connected to SEC system shall be designed, manufactured, tested and installed in accordance with all applicable statutory obligations and shall conform to the relevant SEC standards current at the time of the connection of the installation to SEC system.

The Consumer shall undertake to comply with the following:

- Arrange all necessary requirements and systems to connect Large Scale PV System to SEC system including compliance with security and safety requirements, providing necessary equipment.
- Terms and conditions of offer to connection, connection agreement, connection conditions, and any other relevant requirement adopted by SEC.
- Not to exceed the authorized Maximum Connected Capacity for exporting to SEC system.

- Not to conduct any action impacting the safety and efficiency of SEC system.
- Cooperate with SEC staff in all matters related to electricity exported to the system.
- All costs associated with the connection of a Large-Scale PV System to SEC system shall be borne by the Consumer.
- Any excess electricity generated by the Large-Scale PV System above the electricity consumed in the Consumer's premises shall be exported to SEC system in accordance with the provisions of the connection agreement.
- If there is a risk for the safety or the security of the system and the public electricity network, SEC is entitled to either disconnect or to require immediate disconnection of the Large-Scale PV System from the system.

2 REFERENCE DOCUMENTS

[1] The Saudi Arabian Distribution Code Updated Version: April 2021 (in this document referred to as "Distribution Code")
[2] The Saudi Arabian Grid Code (in this document referred to as "Grid Code")
[3] The Saudi Building Code Electrical Requirements (SBC401) – 2007
[4] SASO IEC 62116:2017, Utility-interconnected photovoltaic inverters - Test procedure of islanding prevention measures
[5] IEC 61000-3-2:2014 Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)
[6] 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
[7] IEC 61000-13-15:2011 table -7. 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
[8] IEC/TR 61000-3-15:2009, Assessment of low frequency electromagnetic immunity and emission requirements for dispersed generation systems in LV network
[9] SASO IEC 62109-1:2017 – Safety of power converters for use in photovoltaic power systems - Part 1: General requirements
[10] SASO IEC 62109-2:2012 – Safety of power converters for use in photovoltaic power systems - Part 2: Particular requirements for inverters.
[11] DS3: Rate of Change of Frequency (ROCOF) Workstream, EirGrid 2011.
[12] Technical Standards for the Connection of Small-Scale Solar PV Systems to the LV and MV Distribution Networks of SEC – April 2018

3 COMPANION DOCUMENTS

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

[1] CESI_SEC-DREG Health and Safety Requirements for Large-Scale PV_Final.docx
[2] CESI_SEC-DREG Large-scale PV - Best Practice Design v1.0_Final.docx
[3] CESI_SEC-DREG Manual for the maintenance of Large-Scale PV Systems_Final.docx
[4] CESI_SEC-DREG PV components and recommendations for PV larger than 2 MW.docx
[5] CESI_SEC-DREG Inspection and Testing Checklists for Large Scale Solar_Final.docx
[6] CESI_SEC-DREG Inspection and Testing Guidelines Solar Greater than 2 MW_Final.docx
[7] CESI_SEC-DREG Connection Guidelines for Large-Scale PV_Final.pdf

4 TERMS AND DEFINITIONS

Active Power - Active Power is the real component of the apparent power, expressed in watts or multiples thereof (e.g. kilowatts (kW) or megawatts (MW)). In the text this will be generically referred as P or Pnom in case of nominal active power of equipment.
Auxiliary Supply Power – Electricity supply to auxiliary systems and services such as Interface Protection or circuit breaker and contactor opening coils.
Exit Point – The physical point at which Consumer's Plant or apparatus is joined to the SEC Distribution System.
Consumer – Any Person supplied with electricity services for his own consumption. In this context, this term will also be used to refer to a User owning a Solar PV System. This term has also the same meaning of Customer, as defined in the Distribution Code. As per WERA Regulations, a Consumer is considered Eligible when it meets both the requirement of the same Regulations and the Connection Conditions as defined in the Distribution Code.
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.
Distribution System / Network – The system which consists of electric lines, electric plant, transformers and switchgear and which is used for conveying electricity to final Customers / Consumers. It 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 nominal voltage lower than 1kV AC or 1.5 kV DC. The LV Distribution System nominal voltages in KSA are 400/230V, 380/220V and 220/127V.
- A Medium Voltage (MV) Distribution System is a network with nominal voltage included in the range from 1kV AC up to 69 kV. The MV Distribution System nominal voltages in KSA are 13.8, 33 and 69kV.

For avoidance of doubt, the term Distribution Network will be preferred in this document in place of Distribution System.
Interface Protection (IP) - The electrical protection required to ensure that either the Solar PV System and/or any Solar PV Unit is disconnected for any event that could impair the integrity or degrade the safety and reliability of the distribution network.
Islanding - Situation where a portion of the distribution network, containing generating plants, becomes physically disconnected from the rest of the distribution network and one or more generating plants maintain a supply of electrical energy to such isolated part of the distribution network.

Loss of Mains (LOM) – Represents an operating condition in which a distribution network, or part of it, is on purpose or in case of fault separated from the main power system with the final scope of de-energization. This denotes also the protection which detects this condition, and it is also known as anti-islanding.

Main Meter - Is the bidirectional device installed at the Exit Point which measures the amount of electric energy actually exchanged (either in import or in export) by the Consumer with the distribution network.

Maximum Connected Capacity - The Eligible Consumer maximum PV installed generation capacity which SEC allows to operate in parallel to the Distribution Network. The Maximum Connected Capacity shall not exceed for any reasons the limits set forth by WERA Regulations.

Solar PV System Meter - Is the device installed at the common output point of the Solar PV > 2 MW System and which measures the total energy produced from the Solar PV Units. As per WERA Regulations this will be required only for Solar PV Systems with Maximum Capacity >100kW

Rated active power – Represents the sum of the nominal active power of all the Solar PV Units which compose the Solar PV System; it is generally referred as Pnom.

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.

Reactive Power - Represents the imaginary component of the apparent power, usually expressed in kilovar (kVAr) or Megavar (MVAr).

Solar PV system– As per WERA Regulations, a solar PV installation of not more than 2MW that is installed in one Premises and connected in parallel to the Distribution Network. From the purposes of this document, and in line with the definition DCD40 of the Distribution Code, this System is to be considered as a power station with one or more Solar PV Units. Besides, circuits and auxiliary services are also to be considered part of a Solar PV with System. For avoidance of doubt, in this document the generic term Solar PV System will be considered equivalent to Solar PV > 2 MW system.

Solar PV Unit – A group of devices which collect the sun's rays within a Solar PV System, together with all plant and apparatus and any step-up transformer which relates exclusively to the operation of that part of the same Solar PV System. Only units which are inverter based (i.e. Asynchronously connected to the Distribution Network through power electronics devices) are taken into consideration in this document. For the purposes of these Technical Standards, this definition will be equivalent to that of Power Park Module as given in DCD41 of the Distribution Code. For avoidance of doubt, in this document the generic term Solar PV Unit will be considered equivalent to Solar PV > 2 MW Unit.

Switch – Mechanical device capable of making, carrying and breaking currents in normal circuit conditions and, when specified, in given operating overload conditions. In addition, it is able to carry, for a specified time, currents under specified abnormal circuit conditions, such as short-circuit conditions.

THD (Total Harmonic Distortion) – With reference to 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.

5 GLOSSARY

The following acronyms and symbols are used throughout the document:

cos φ	Power factor
WERA	Water & Electricity Regulatory Authority
IP (or I.P.)	Interface Protection
LOM	Loss of Mains
LV	Low Voltage (namely 220/127 Vac or 380/220 Vac or 400/230 Vac)
LVRT	Low Voltage Ride Through
MV	Medium Voltage (namely 13.8kV or 33 kV)
P	Active power
Pnom	Nominal active power of equipment
p.u. (or pu)	per unit
PV	(Solar) Photovoltaic
Q	Reactive Power
ROCOF	Rate Of Change Of Frequency expressed in Hz/s.
S	Apparent Power
Sn	Nominal Apparent Power
SEC	Saudi Electricity Company
V	Voltage
Vnom	Nominal Voltage

6 TECHNICAL REQUIREMENTS

6.1 General requirements

A Solar PV System>2MW shall be connected to SEC Distribution Network, MV, at an appropriate point, called Exit Point. It is the responsibility of SEC to design a suitable process which determines the appropriate Exit Point and assesses the capacity of the network to host the connecting Solar PV System at that point whilst maintaining a stable, reliable and economical operation of the system for all operating conditions.

According to the Distribution Code, if the results of such process highlight that the connecting Solar PV > 2 MW System is likely to cause the network to possibly operate outside of SEC statutory performance standards, SEC has the right to reject the connection application or to propose modifications (for example in terms of Exit Point and/or characteristics of the Solar PV System>2MW) or alternative solutions (for example in terms of network reinforcements) to enable the connection.

The Maximum Connected Capacity of the Solar PV System to be proposed by the Consumer, will be determined in agreement with the specific clauses of WERA Regulations.

6.2 Connection schemes

A Solar PV System shall be in compliance with the connection requirements of SEC, and especially shall meet the following requirements:

- the synchronization, operation and disconnection of the System under normal network operating conditions, i.e. in the absence of faults or malfunctions, shall bear no consequences to the statutory power quality of the network.
- the protection schemes and settings needed for the Solar PV System shall be coordinated with those of the distribution network; they shall therefore be agreed between SEC and the Consumer with the following purpose:
    - faults and malfunctions within the Solar PV System shall not impair the normal operation of SEC distribution network. In particular, any faults that including earth-faults with leakage current internal to the Consumer's installation will be detected and cleared below or at the Exit point before any SEC protection operates.
    - the protection schemes and settings for electrical faults within the Consumer's installation must not affect the performances of the Solar PV System.
    - the protection schemes of the Solar PV System shall be coordinated with those of the distribution network in order to operate properly in case of faults either within the Solar PV System or within the distribution network.

In order to satisfy the above requirements, Figure 1 and Figure 2 present the typical equipment which shall be at least installed for a safe and reliable connection of a Solar PV System to the LV and MV distribution network respectively:

- A Main Switch shall be installed as close as possible to the Exit Point and shall be operated by a protection system in case of internal faults, in accordance with the Distribution Code [1]. If agreed with SEC, it is possible to install more than one main switches in order, for example, to have two separate circuits, one dedicated to the Consumer's loads and one dedicated to the Solar PV System.

[1] For the definition of the requirements of the protection system against faults within the Consumers' installations, please refer to DCC4.2 in the Distribution Code

- The Interface Switch, operated by an Interface Protection, shall be envisaged in the Consumer installation to separate the portion of it containing one or more Solar PV Units from both the remaining part of the Consumer's installation containing only loads and SEC distribution network. For Solar PV Systems whose power exceeds 2MW, a backup is necessary in case of failure on this switch opening.
- The Solar PV Unit Switch shall be installed as electrically close as possible to the terminals of each Solar PV Unit, for the protection and the connection/disconnection of that unit. For the protection issues, the recommendations and requirements of the Manufacturer of the equipment shall apply.

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In case the nominal voltage of the inverters does not match the nominal voltage of the distribution network, a transformer shall be necessary to connect either the Solar PV System or each single Solar PV Unit to the network. The cost of this transformer shall not for any reason be ascribed to SEC and shall be entirely borne by the Consumer solely.

6.3 Choice of Switches

For each of the above-mentioned switches, the choice of the type to be installed (circuit breaker, contactor, disconnecting switch with fuses, etc.) shall be based on:

- the functions the switch shall carry out.
- the characteristics of the Consumer's installation.
- the characteristics of SEC Distribution Network at the Consumer's Exit Point.

Especially, the following criteria shall be adopted:

- the switches, panels and switchgear shall be compliant with the requirements of the Distribution Code,
- the switch(es) of the Solar PV Unit(s) shall be compliant with the Manufacturer requirements,
- electronic switches shall not be used for protective (overcurrent) functions.
- Solar PV Systems connected to the MV Distribution Network and with the Interface Switch on the MV side of the plant, the Interface Switch shall consist of:
    - three-pole withdrawable automatic circuit breaker operated by an undervoltage release, or
    - three-pole automatic circuit breaker operated by an undervoltage release along with an isolator (either upstream or downstream the circuit breaker)

  In any case, the circuit breaker shall be motorized, to allow automatic reclosure once the network disturbances that have led to the trip of the Interface Protection have been cleared. The consensus to the reclosure of the Interface Switch shall be given by the Interface Protection itself, which has then to sense the voltages on the network side (as represented in the Connection Schemes,) and not on the Solar PV System side of the Interface Switch
- Solar PV Systems connected to the MV Distribution Network and with the Interface Switch on the LV side of the plant, the interface switch shall consist of either:
    - motorized automatic circuit breaker or switch disconnector operated by an undervoltage release, or
    - AC3 contactor which operates on all the poles (i.e. phases and neutral).

  in order to allow automatic reclosure once the network disturbances that have led to the trip of the Interface Protection have been cleared. The consensus to the reclosure of the Interface Switch shall be given by the Interface Protection itself, which has then to sense the voltages on the network side and not on the Solar PV System side of the Interface Switch.

- any switch shall have a breaking and making capacity coordinated with the rated values of the Consumer's installation, taking into consideration both the generating plant and the contribution to short circuit from the Distribution Network.
- the short time withstand current of the switching devices shall be coordinated with the maximum short circuit power at the Exit Point[2];
- in case of loss of auxiliary supply power to the switchgear, a secure disconnection of the Interface Switch is required immediately.

The function of the Interface Switch can be combined with either the Main Switch or the Solar PV Unit Switch in a single switching device[3]. In case of a combination of these, the single combined switching device shall be compliant with both the requirements of the interface switch and of either main switch or PV unit switch, according to the combination chosen. As a consequence, at least two switches in series shall be always present between a Solar PV Unit and the Exit Point.

6.4 Protection of the installation against faults

The electrical protections required for the connection of a Solar PV System>2MW to SEC Distribution networks are of concern in the present document. These additional protections shall be checked and approved by DPED-SEC. Other protections shall also be installed to protect the Consumer's electrical assets as per SEC protection policy. All protections shall be graded and co-ordinated with SEC upstream protections and downstream protections within the solar installation. Any faults down to the Exit Point shall be cleared at the same point or below, without impacting SEC distribution network.
Where overcurrent protection is required for the safety of the equipment, whether this be part of the Solar PV System or not, automatic disconnection of the faulted circuit shall be accomplished.

[2] Information about the maximum prospective short-circuit level of SEC distribution networks is reported in DCC4.5.1 of the Distribution Code.

[3] 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 Consumer's facility when the interface switch is opened, that is a lack of supply will also affect the Consumer load.

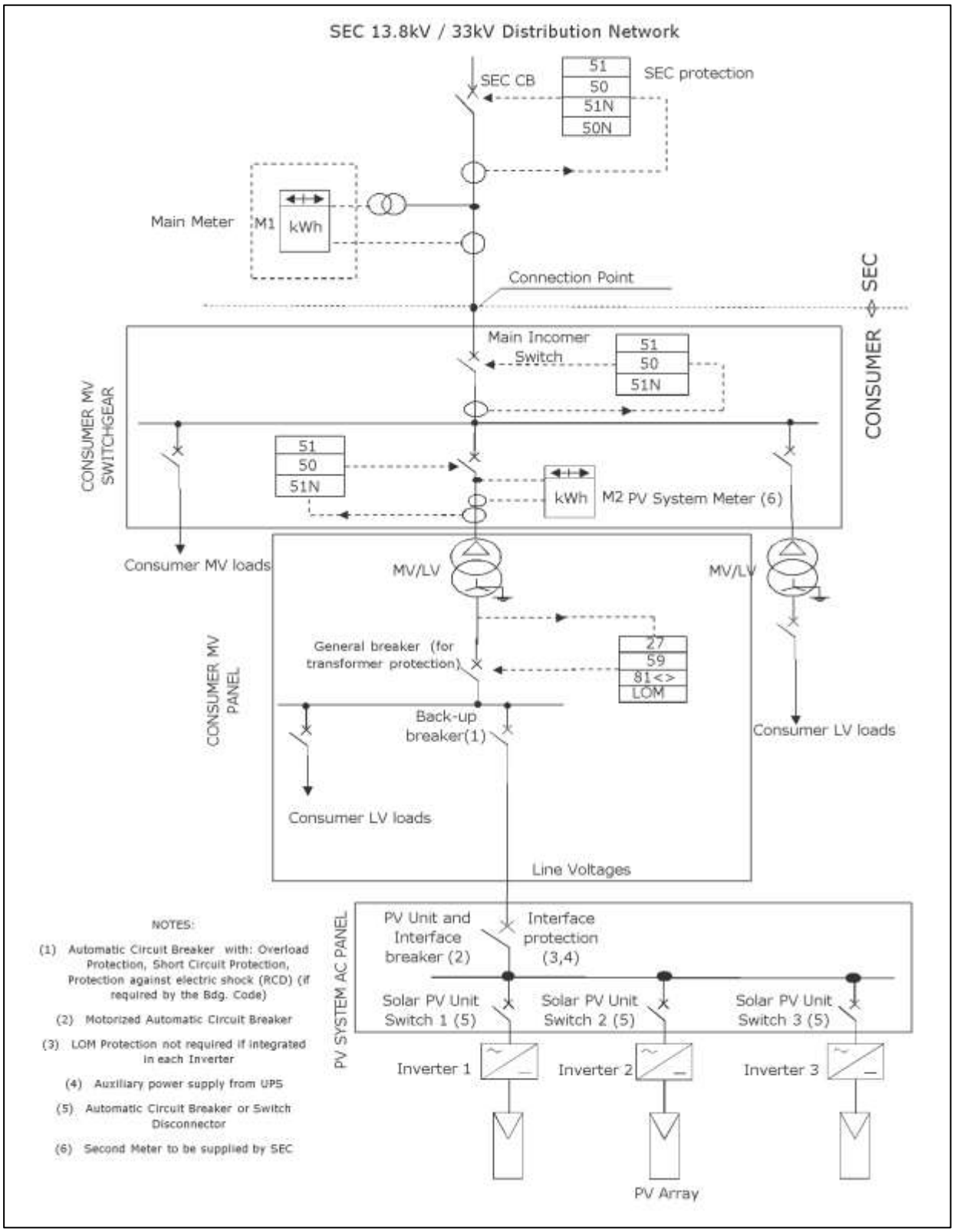


Figure 1 - Schematic representation for the connection of a Solar PV > 2 MW System with SEC MV Distribution Network scheme 1

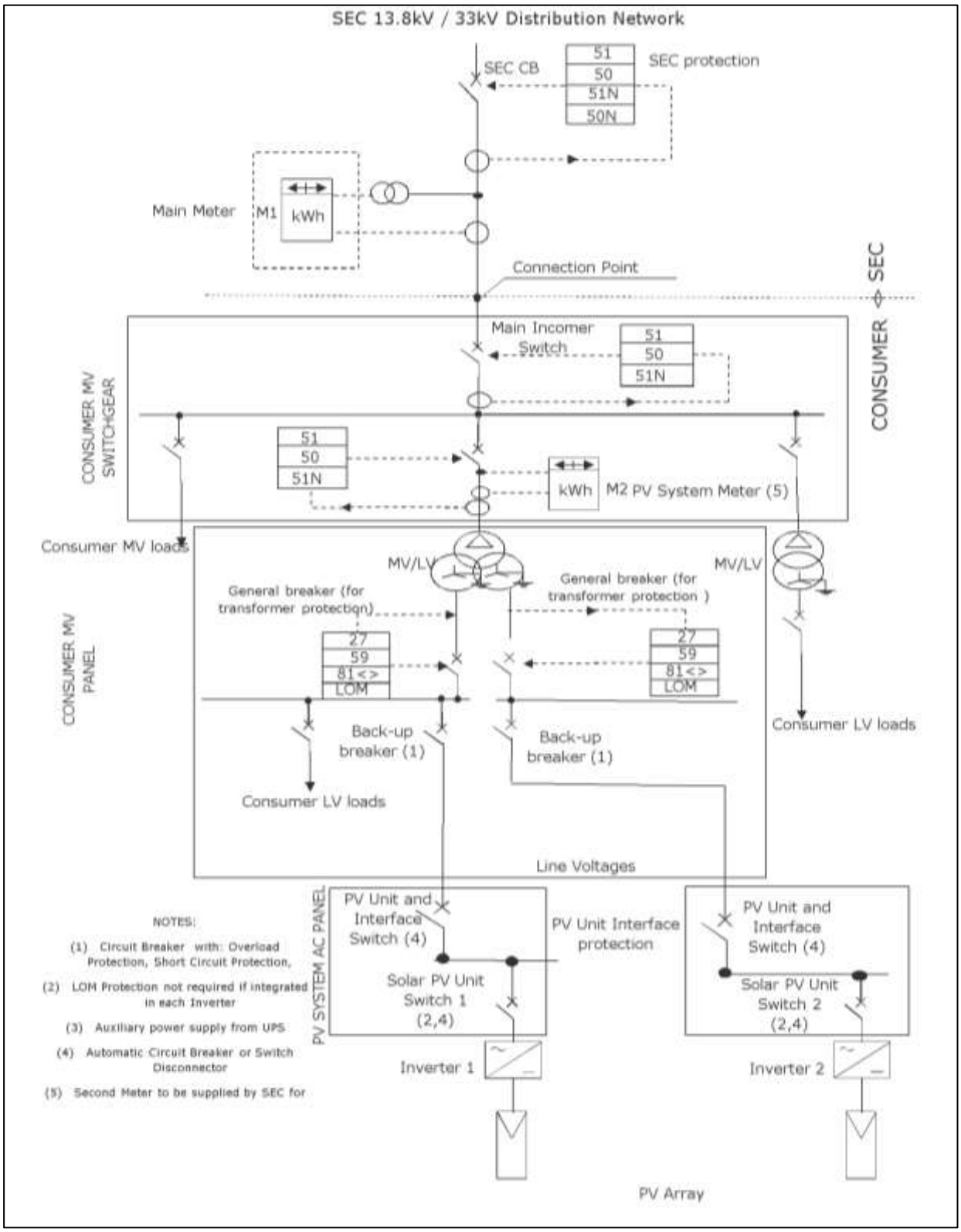


Figure 2 - Schematic representation for the connection of a Solar PV > 2 MW System with SEC MV Distribution Network (either 13.8 or 33kV) scheme 2

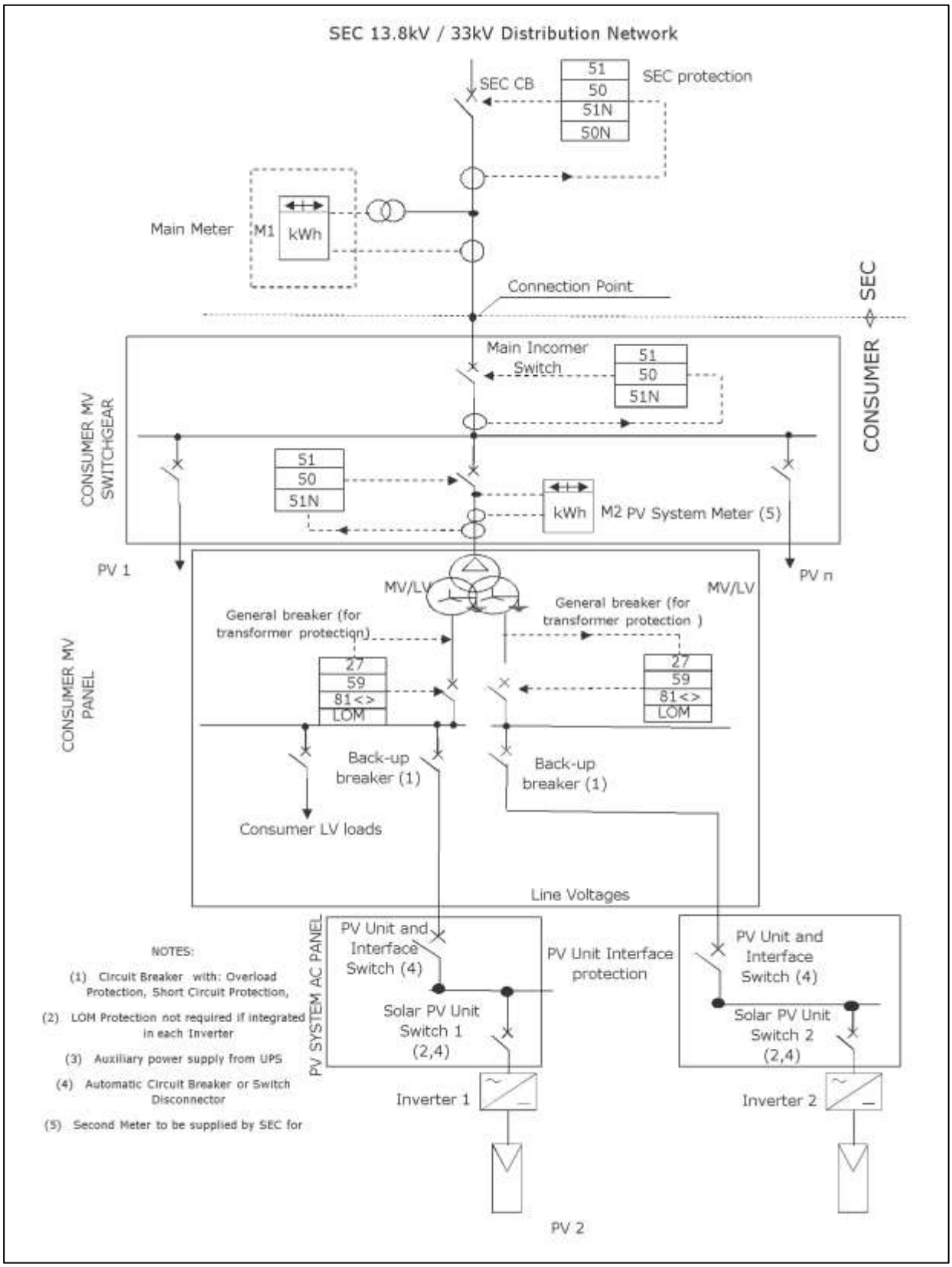


Figure 3 - Schematic representation for the connection of a Solar PV > 2 MW System with SEC MV Distribution Network (either 13.8 or 33kV) scheme 3 (multiple PV connections for higher sizes)

6.5 Operating ranges

Solar PV Solar PV Systems shall be capable of remaining connected to the Distribution Network and of operating stably, as specified in this document, in the frequency and voltage ranges for the time periods specified in the tables below, regardless of the type and settings of the protection systems:

Table 1: Frequency operating range

Below Nominal Frequency (Hz)	Above Nominal Frequency (Hz)	Operation Requirement
58.8 – 60.0	60.0 – 60.5	Continuous
57.5 – 58.7	60.6 – 61.5	for a period of 30 minutes
57.0 – 57.4	61.6 – 62.5	for a period of 30 seconds

Table 2: Voltage operating range

Voltage range at the Exit Point	Operation Requirement
90-110% Nominal Voltage	Continuous

6.6 Immunity to disturbances

6.6.1 Low Voltage Ride Through (LVRT) capability

Solar PV Systems shall contribute to the stability of the overall power system by providing immunity towards dynamic voltage changes, especially those due to faults on the higher voltage level networks. The requirements below apply to all kind of disturbances (1ph, 2ph and 3ph faults) and are independent of the Interface Protection settings (see 6.9.4) which overrule the technical capabilities of a Solar PV System. Therefore, whether the Solar PV System will stay connected or not will also depend on settings of the Interface Protection.

A Solar PV System with a Maximum Connected Capacity greater than 2MW shall be capable to stay connected to the distribution network as long as the voltage at the Exit Point remains above the voltage-time diagram of Figure 4. The p.u. voltage shall be calculated with respect to the nominal voltage at the Exit Point. For three-phase generating systems, the smallest phase to phase voltage shall be evaluated. The compliance to such LVRT requirement shall apply to all equipment that might cause the disconnection of the Solar PV System, i.e. Inverters and Interface Protection.

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

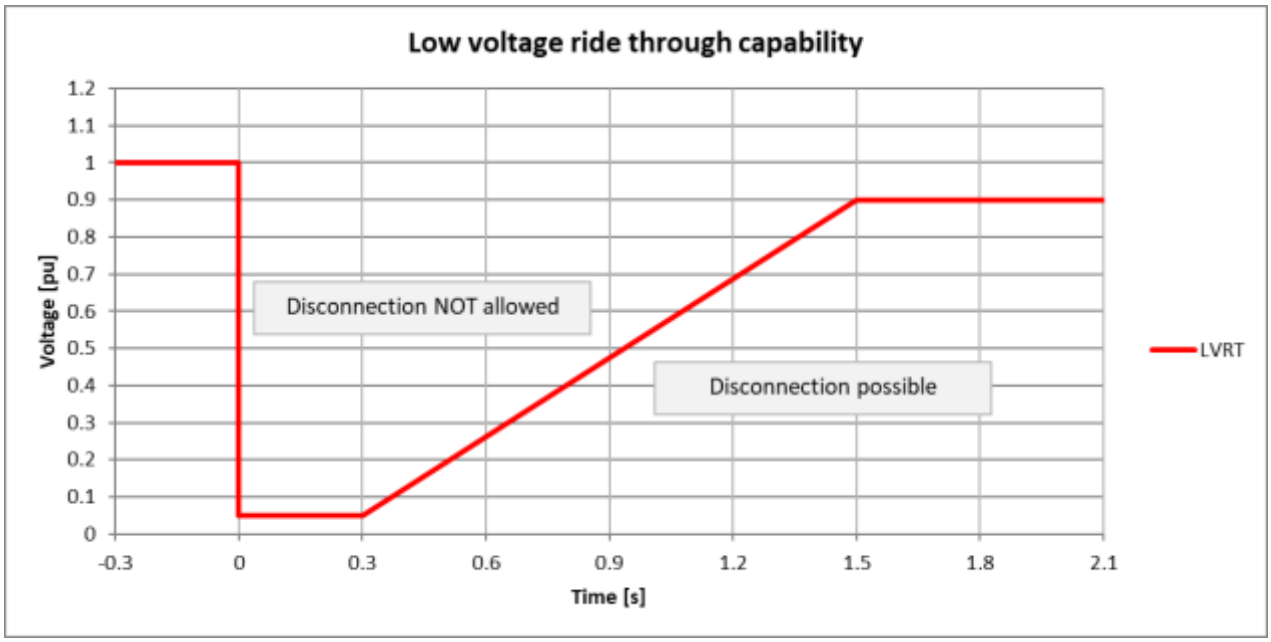


Figure 4 – LVRT characteristic for Solar PV > 2 MW System

6.6.2 ROCOF withstand capability

Solar PV Systems, when generating power, shall be able to go through frequency transients with frequency within the normal operating range (see 6.5) and with ROCOF value up to 2.5 Hz/s[4] [11] [12].
In the case the Loss Of Mains (LOM) protection, as described in 6.9.4, implements a ROCOF-based method, the threshold of the LOM function shall not cause the intervention of the protection within the immunity ranges as specified in this paragraph.

6.7 Requirements for the frequency stability of the power system

6.7.1 Active power response to frequency variations

A Solar PV System shall be capable of activating the provision of active power response to over-frequency transients according to the curve of Figure 5, with frequency threshold and droop settings adjustable and to be specified by SEC;

- the frequency threshold shall be settable at least between 60 Hz and 62 Hz inclusive; if not differently specified by SEC, the threshold shall be set to 60.2Hz.
- the generated active power Pgen shall be referred to the actual active power value Pact when the threshold is reached, and the active power response is activated.
- the droop settings shall be between 2% and 8% in steps of a maximum of 1 %; if not explicitly specified by SEC, the droop shall be set to 3.83%.

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

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

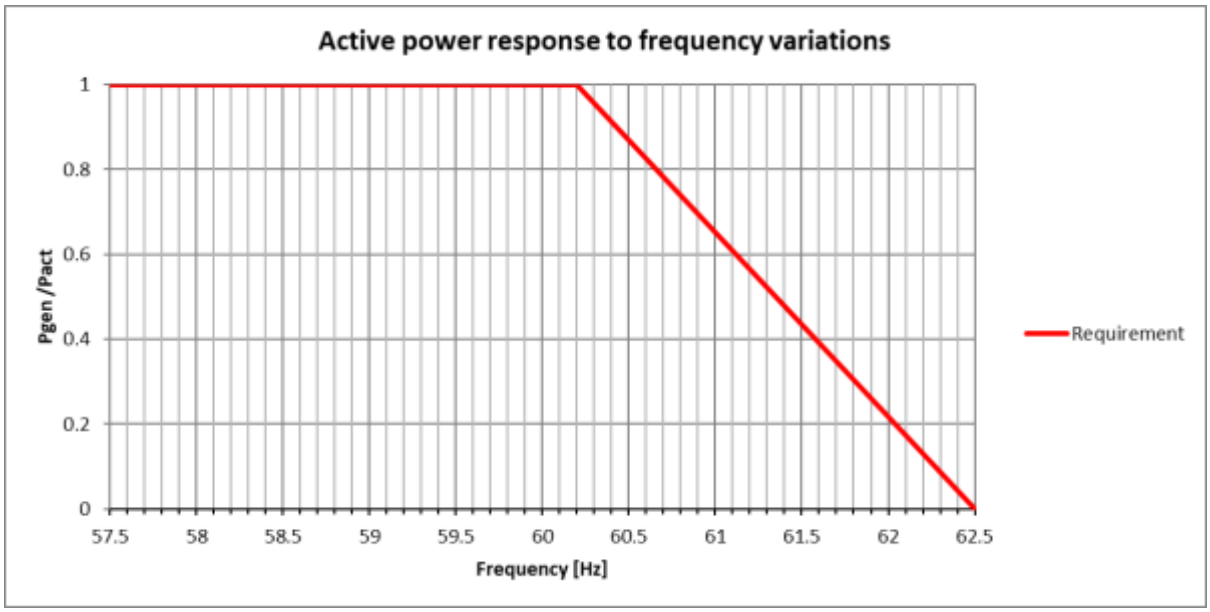


Figure 5 – Active power frequency response for Solar PV > 2 MW System

6.7.2 Active power delivery at under-frequencies

When a Solar PV 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, any decrease of the maximum reachable active power output shall be kept above the curve of Figure 6.

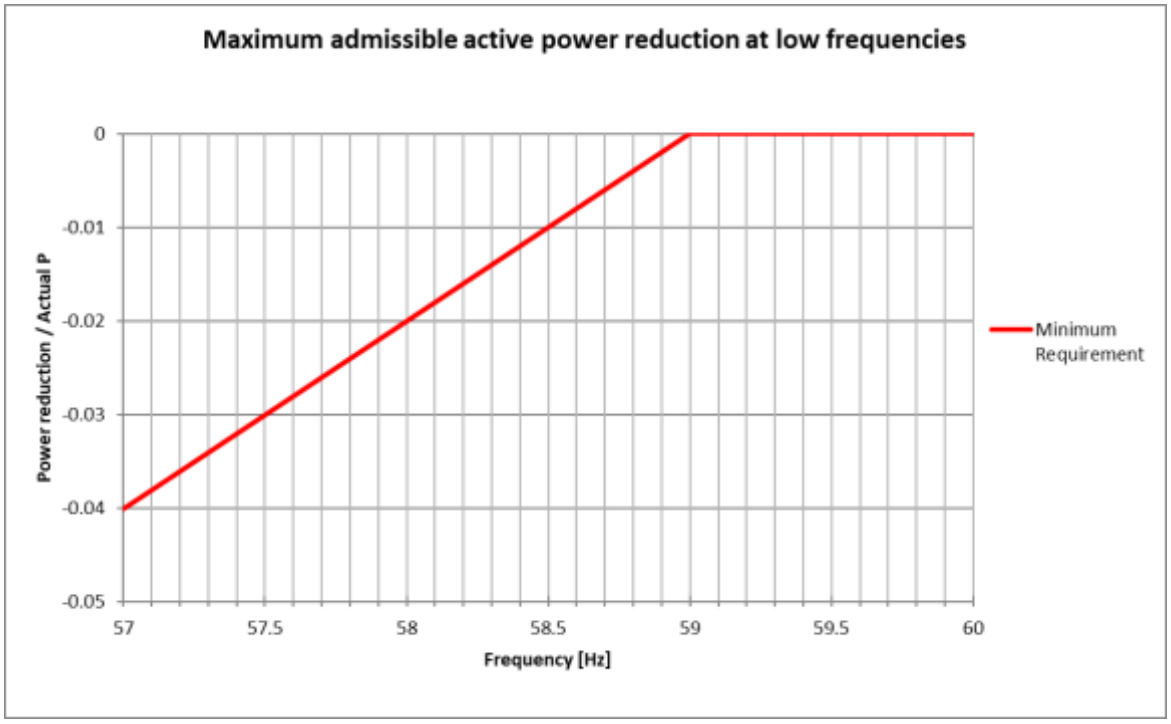


Figure 6 – Maximum admissible output power reduction at low frequencies

6.7.3 Remote limitation of active power

A Solar PV System with a Maximum Connected Capacity greater than 2 MW shall be equipped with an interface (input port) which is able to receive, from a remote-control center, an instruction requiring the reduction of the active power output.

The reduction of active power shall be carried out as fast as possible and with an accuracy greater than 5% of the nominal active power of the Solar PV System.

In accordance with the provisions set forth in 6.9.6, SEC shall have the right to specify further requirements in terms of equipment, communication protocol, information to be exchanged and/or time of execution, which allow to integrate such feature into the control systems of its distribution network and which allow to remotely limit the active power output of the Solar PV Units connected to its network.

6.8 Requirements for the voltage stability of the power system

6.8.1 Reactive power capability

When voltage and frequency at the Exit Point are within their normal operating ranges, a Solar PV System shall be able to provide reactive power in any operating point within the boundaries of the reactive power capability curves defined in Figure 7[5].

According to this capability, the inverters will be able to either generate or absorb inductive reactive power from the Distribution Network, in order to participate to voltage support at the Exit Point, for any of the values of active power generated by the Solar PV System.

Three areas are visible in Figure 7:

- Triangular area, required for inverters included in Solar PV Systems whose Maximum Connected Capacity is smaller than or equal to 2MW: for an active power ranging from zero to the nominal power of the Solar PV System (i.e. 1 p.u.), the inverter shall be capable of either generating or absorbing inductive reactive power Q at a power factor cosφ of 0.95 (boundary points of the triangular curve in the chart);
- Rectangular area required for inverters included in Solar PV Systems whose Maximum Connected Capacity is greater than 11kW: these shall 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 cosφ of 0.95 (apex points of the rectangular area for P=1 p.u.).
- Design free area, that is an area which can be optionally exploited by the inverter Manufacturers.

With reference to Figure 7, when the Solar PV System operates in the design free area (i.e. above its nominal active power because of favorable environmental conditions), it is allowed to reduce the reactive power capability according to the widest possible technical capability of the Solar PV Units.

When the Solar PV System is operating above a threshold of 10 % of its nominal apparent power Sn, the required reactive power Q shall be provided with an accuracy of ±2% Sn. Below the threshold of 10% of Sn, deviations above 2% of accuracy are permissible; nevertheless, the accuracy shall always be as good as technically feasible and shall not exceed 10% of Sn.

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

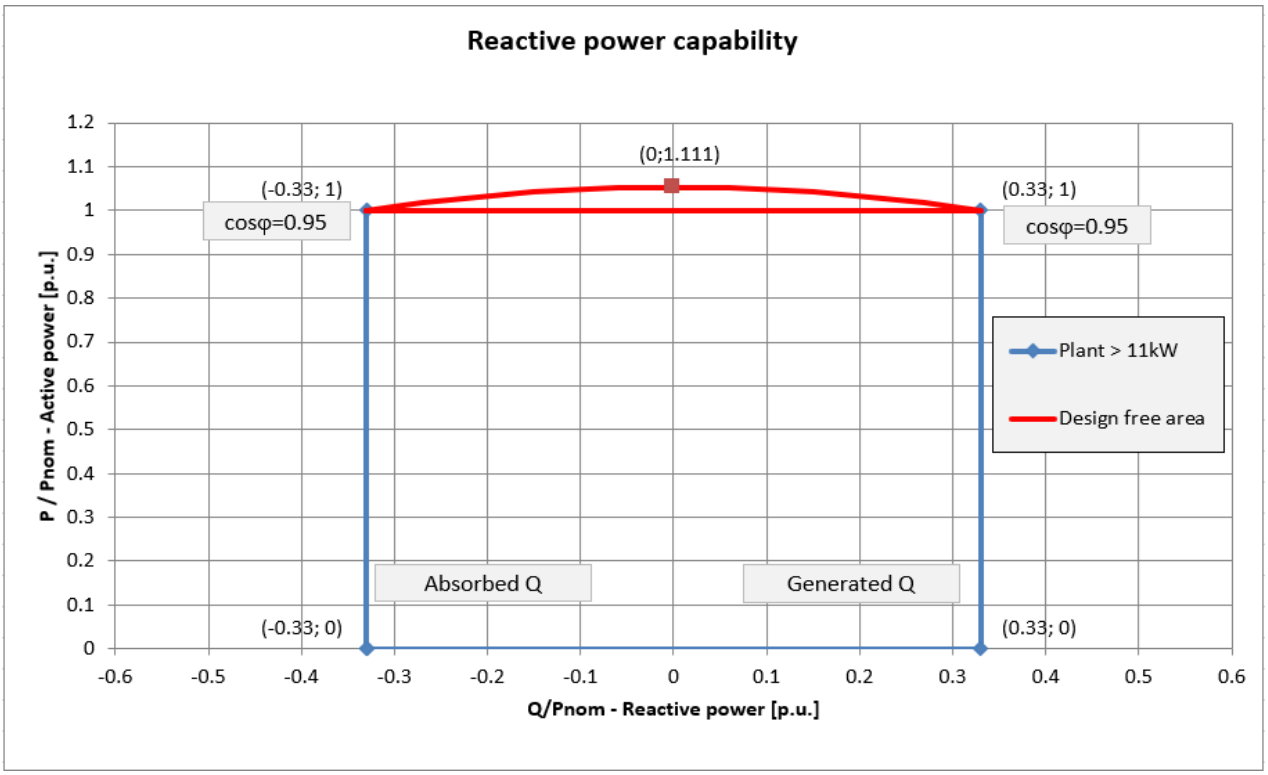


Figure 7 – Reactive power capability

6.8.2 Reactive power control modes

A Solar PV System shall be capable of operating in the control modes stated below, within the limits of its reactive power capability as expressed in 6.8.1:

- fixed Q: the reactive power is controlled in order to have a fixed value.
- fixed cos φ: the reactive power is controlled in order to have a fixed power factor.
- cos φ (P): the reactive power is controlled in order to have a power factor 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 activation, deactivation and configuration of the control modes shall be field adjustable. It is the responsibility of SEC to communicate to the Solar PV System's owner which of the above-mentioned reactive power control mode shall be activated.

6.8.2.1 Fixed control modes

When operated with fixed Q or fixed cos φ control mode, the Solar PV 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 Solar PV System. If not explicitly specified by SEC, the default set point values shall be 0 for fixed Q control mode and 1 for fixed cos φ control mode.

For a Solar PV System with a Maximum Connected Capacity greater than 2MW, the Solar PV System shall also be able to receive the set-point from a remote control center in accordance with the provisions set forth in 6.9.6.

6.8.2.2 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 8 shall be configurable within the control systems of the Solar PV 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 SEC. If not explicitly specified by SEC, these parameters shall be set as indicated below:

- A P = 0 Pnom cos φ = 1
- B P = 0.5 Pnom cos φ = 1
- C P = Pnom cos φ = 0.95 Lag
- D P = Pnom cos φ = 0.95 Lead

where Pnom is the active nominal power of the Solar PV 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 6.8.1.

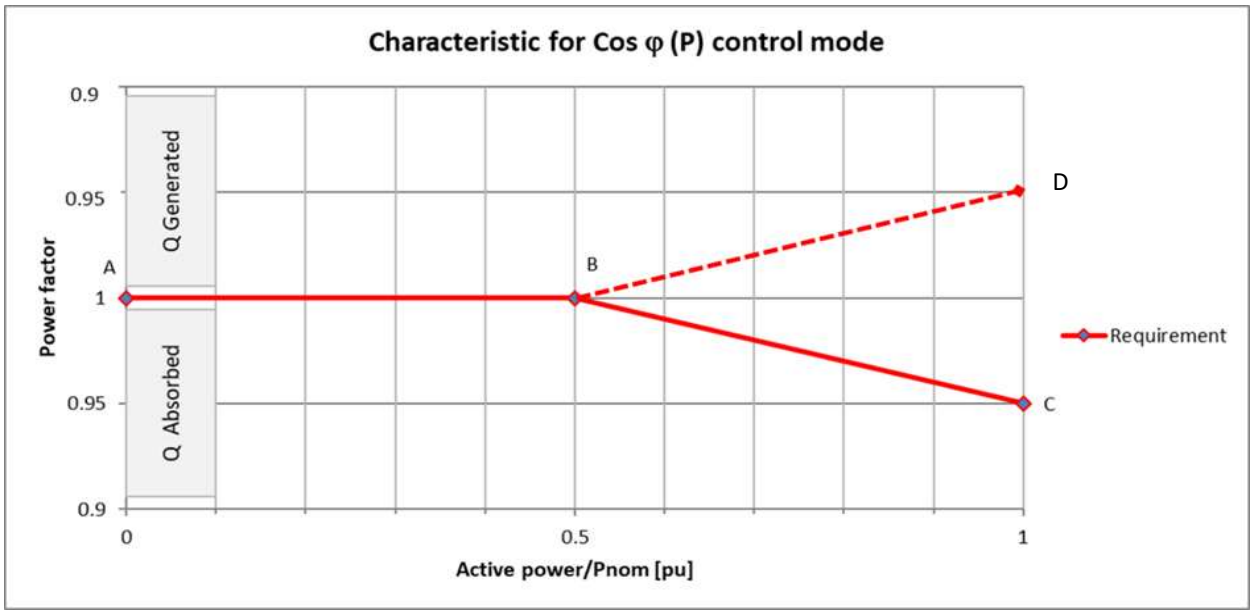


Figure 8 – Characteristic for Cos j (P) control mode

The implementation of a lock-in and lock-out voltage level shall be configurable, each in the range 90% to 110% of the nominal voltage at the Exit Point: the contribution is activated when the voltage at the Exit Point exceeds the lock-in voltage and is deactivated when the voltage at the Exit Point drops below the lock-out voltage. When the contribution is not activated, the Solar PV System shall be controlled with a unity power factor (cos φ = 1).

6.8.2.3 Reactive power support as a function of the voltage Q(V)

For Solar PV Systems with a Maximum Connected Capacity greater than 2 MW, for such control mode, a characteristic with a minimum and maximum reactive power value and three connecting lines according to Figure 9 shall be configurable.

It is SEC responsibility communicate the parameters to be configured in case this support is required from Solar PV Systems.
The values shall be assigned with the following criteria; therefore, the parameter ranges available in the inverter shall not limit this setting:

- Qmax and –Qmax correspond to the capability curve boundaries as per Figure 7 (e.g. 0.33 Pnom, where Pnom is the nominal power of the Solar PV Unit)
- V1 > [27<] threshold of Interface Protection
- V4 < [59>] threshold of Interface Protection
- V2< Vnom <V3

Possible default values can be the following, unless differently agreed with SEC:
V1 = 0.9 Vnom
V4 = 1.1 Vnom
V2=0.95 Vnom, V3=1.05 Vnom

where Vnom is the nominal Voltage at the Exit Point.

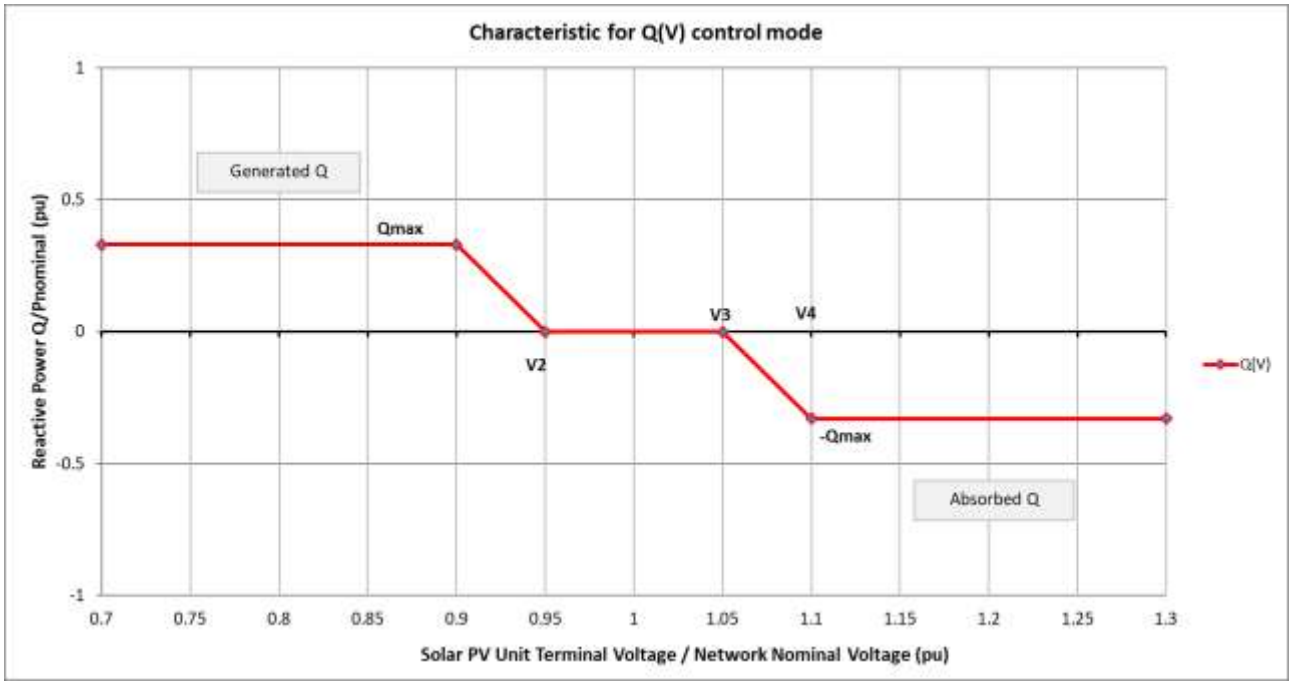


Figure 9 – Characteristic for Q(V) control mode

6.8.3 Power reduction at increasing voltage

In order to avoid the disconnection due to overvoltage protection, a Solar PV System is allowed to reduce its power output (active and/or reactive power) as a function of the rising voltage at the Exit Point. The implemented logic can be chosen by the Manufacturer/Consumer. Nevertheless, the implemented logic shall not cause steps or oscillations in the power output of the system.

6.8.4 Reactive current injection during a fault

The provision of reactive current during a fault is currently not required for Solar PV Systems. Such feature might be introduced in the future and only for MV connected Solar PV Systems, in a scenario of a growing penetration level of distributed generation and a decreasing short circuit power of the power system of the KSA.

6.9 Requirements for the management of the power system

6.9.1 Connection conditions

A Solar PV System is allowed to be connected to the network and to start to generate electrical power due to normal operational start-up, when the voltage and frequency are within the following range for at least the observation time:

- Frequency range 59.5 Hz ≤ Frequency ≤ 60.05 Hz.
- Voltage range 95% Vnom ≤ Voltage ≤ 105% Vnom (Vnom= nominal voltage at the Exit Point).
- Minimum observation time 30s.

Synchronizing a Solar PV System> 2MW with the distribution network shall be fully automatic, that is it shall not be possible to manually close the switch between the two systems to carry out the synchronization[6].

The synchronization of a Solar PV System to the distribution network shall not create a transient voltage variation at the Exit Point of more than 4% of nominal voltage.

After the connection, a Solar PV System shall follow its target active power value with a variation rate not greater than 10% Pnom/min, where Pnom is the nominal active power of the Solar PV System.

The active power target shall be the maximum available active power output that the Solar PV System can generate, taking into account the environmental conditions (irradiation, temperature, …), except for the operating conditions when the power output shall follow changes due to the provision of some of the services specified in this document (see 6.7.1, 6.7.3 and 6.8.3).

6.9.2 Remote disconnection

A Solar PV System with a Maximum Connected Capacity greater than 2MW shall be equipped with a logic interface (input port) in order to disconnect from the network following an instruction received at its interface.

In accordance with the provisions set forth in 6.9.6, SEC shall 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 feature into the control systems of its distribution network and to allow the remote disconnection of the Solar PV Systems connected to its network.

6.9.3 Automatic reconnection after tripping

After the trip of the interface protection, a Solar PV System > 2MW is allowed to reconnect to the network only if the voltage and frequency are within the following range for at least the observation time:

- Frequency range 59.5 Hz ≤ Frequency ≤ 60.05 Hz.
- Voltage range 95% Vnom ≤ Voltage ≤ 105% Vnom (Vnom= nominal voltage at the Exit Point).
- Minimum observation time 300s.

After reconnection, the Solar PV System shall return to its target active power value with a variation rate not greater than 10% Pnom/min, where Pnom is the nominal active power of the Solar PV System.

6.9.4 Interface Protection

The purpose of the interface protection is to:

- disconnect the Solar PV System from the Distribution Network in the following cases

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

  - the Distribution Network (or the feeder) the Solar PV System is connected to is de-energised from the main source of supply. De-energisation can happen automatically due to protection system operation or manual/electrical disconnection. Electrical/manual disconnection in the Distribution Network can happen either remotely by SEC SCADA system or by local switching.
  - the voltage and/or frequency values at the Exit Point are out of the normal operating ranges as defined in 6.5.
- prevent the Solar PV System, when generating power, to cause over-voltages in the distribution network it is connected to.

It is not the purpose of the interface protection to:

- disconnect the Solar PV System from the Distribution Network in case of faults within the Consumer's installation; for such issues, the requirements for the connection of passive customers shall apply (refer to Distribution Code).
- prevent damages to the Consumer's equipment (generating units or loads) due to faults/incidents (e.g. short circuits) in the Distribution Network or on the Consumer's installation; for such issues, the recommendations and requirements of the manufacturers of the equipment shall apply.

The interface protection shall be a dedicated device which acts on the interface switch.

The interface protection shall command the interface switch; for a Solar PV System with a Maximum Connected Capacity greater than 2MW, unless explicitly agreed by SEC, only one interface protection and one interface switch shall be used.

For a Solar PV System with a Maximum Connected Capacity greater than 2MW, the interface protection shall additionally act on another switch (backup switch) with a proper delay in case the interface switch fails to operate. The backup switch may consist of a dedicated switch or an already existing switch[7]. When the back-up switch is triggered because the interface switch has failed to open, only manual reclosure shall be possible[8].

For a Solar PV System with a Maximum Connected Capacity greater than 2MW, the power supply of the interface protection shall include an uninterruptible power supply.

The loss of the auxiliary voltage on either the interface protection or on the Solar PV System's control system shall trigger the interface switch without delay.

The protection functions required in the Interface Protection are the following:

- Undervoltage [27]
  - One threshold [27<] in the range [20%; 100%] of the nominal voltage at the Exit 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 of the nominal voltage at the Exit Point adjustable by steps of 5%, and delay time in the range [0.1s;5s] adjustable in steps of 0.05s.
- Overvoltage [59]
  - One threshold [59>] in the range [100%; 120%] of the of the nominal voltage at the Exit Point adjustable by steps of 1%, and delay time in the range [0.1s;100s] adjustable in steps of 0.1s;

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

[8] 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 [59>>] in the range [100%; 130%] of the of the nominal voltage at the Exit Point adjustable by steps of 1%, and delay time in the range [0.1s;5s] adjustable in steps of 0.05s.

- Overfrequency [81>]
  - One threshold [81>] in the range [60Hz; 63Hz] 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 [60Hz; 63Hz] adjustable by steps of 0.1Hz, and delay time in the range [0.1s;5s] adjustable in steps of 0.05s.
- Underfequency [81<]
  - One threshold [81<] in the range [57Hz; 60Hz] 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 [57Hz; 60Hz] adjustable by steps of 0.1Hz, and delay time in the range [0.1s;5s] adjustable in steps of 0.05s.
- 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 used to detect unintentional islanding situations. The present document does not intend to specify the method to be used to achieve the goal but rather its efficacy; for such a reason, the only requirement on LOM protection is that the protection function shall be tested in accordance with SASO IEC 62116 or other equivalent standard, which provides procedures to evaluate the performance of islanding prevention measures used with utility-interconnected Solar PV Systems.

The LOM protection functions shall have the possibility to be excluded or the LOM settings to be modified suitably.

The present standard recognizes that it may not be straightforward for IP manufacturers to define settings of the LOM protection which can be efficient for all the current and future operating conditions of SEC distribution networks. This is especially the case of the most common passive methods currently used for the implementation of such function within a dedicated protection device (i.e. ROCOF and vector jump). The present standard also acknowledges that a LOM protection function implemented within a solar PV inverter through active methods (for example frequency shift), can be efficient under all operating conditions of the network. For such reasons, it is allowed that, for a Solar PV System of capacity larger than 2MW, the LOM protection function be integrated in each single inverter of the system, provided that the built-in LOM protection function of the single inverter has been tested according to SASO IEC 62116 or other equivalent standard. In these cases, and for the avoidance of doubt, the remaining under/over frequency & voltage protection functions of the interface protection have to be built into a dedicated protective device as stated above.

In any case, the LOM protection, irrespective of its actual position, i.e. either integrated in a dedicated Interface Protection or built-in in the inverter, shall detect island operating conditions and cease to energize the Distribution Network within two seconds of the formation of the island, unless differently specified by SEC on the basis of 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 shall be applied to the interface protection and shall ensure the correct tripping of the Solar PV System under specific conditions. The settings shall be chosen so that, in case a fault within

the distribution network triggers the network protection systems (which in turn disconnect the faulty feeder), all the Solar PV Systems are disconnected before the attempt of reclosure in the MV distribution network takes place.

ANNEX B proposes default settings for 27, 59 and 81 protection functions. Such settings shall be actually applied to the Interface Protection of a Solar PV System only in case no other settings have been explicitly specified and communicated by SEC.

Moreover, the Interface Protection shall have at least two configurable digital inputs which may be used in the future[9] by SEC for transfer trip, remote tripping or any other function that may be necessary to increase the capacity of the distribution networks to host distributed generation while keeping an acceptable level of reliability and security.

6.9.5 Protection and Control Ranking Priority

All Solar PV systems shall be designed and manufactured in a way that respects the priority ranking for the protections provided in this section. The purpose of the priority ranking is to avoid the confliction between 2 or more functions that has to be implemented at the same time. For instance, if there is an internal fault within the Solar PV system and at the same time there is an under frequency problem in the network that indicates that the Solar PV system that was generating power to the network shall maintain its operation and stay connected.

In this case which of the 2 function should prevail over the other? According to the below priority ranking the internal fault inside a Solar PV system has the priority and the disconnection shall take place. the protection and control devices of a Solar PV system shall be organized in accordance with the following priority ranking (from highest to lowest):

1. Protection of the PV Units
2. Protection against faults within the Consumer'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

6.9.6 Monitoring, remote control and information exchange

Adequate information concerning the Consumers connected to the Distribution Networks is a prerequisite for enabling SEC to maintain the stability, reliability and security of its networks. SEC needs to have a continuous overview of the state of the network, which may require, in some cases, updated information on the operating conditions of the Solar PV Systems connected to its Distribution Networks, as well as the possibility to communicate with these plants in order to direct the operational instructions set forth by the provisions of the present document.
Such requirements are usually needed in case of growing penetration level of the Solar PV Systems in the distribution networks; they may also be introduced in the framework of other initiatives dedicated, for example, to the optimization of the control performances of the network.

[9] In a scenario of growing penetration level of distributed generation in the distribution networks of the KSA

A Solar PV System with Maximum Connected Capacity greater than 2MW shall therefore have provision for bi-directional communication exchange which can be used for the exchange of information with SEC. Once actually needed for the operation of the network, in accordance with a cost/benefit approach, SEC shall have the right to specify additional requirements concerning especially:

- data, which shall be collected and sent to SEC in real-time or periodically, related to the operating conditions of the Solar PV System.
- operational instructions sent by SEC which shall be executed by the Solar PV System; such instructions shall be compliant with the requirements indicated in the present standards (especially the requirements of 6.7.3 and 6.9.2);
- Communications channels and protocols to be used for the above requirements.

If technically possible, SEC may take advantage of already existing communication channels, such as smart metering infrastructure, in order to facilitate the integration of the monitoring activities into its ICT architecture and reduce the costs of implementation.

6.9.7 Power factor

Any installations containing a Solar PV System shall comply with the power factor limits, as measured at the Exit Point, indicated in the Distribution Code[10] (amended to date).

6.9.8 Power quality

6.9.8.1 Voltage deviation

Under normal operating conditions, the connection and operation of a Solar PV System shall not cause the voltage at its Exit Point and at the Exit Point of any other Consumers connected to the same Distribution Network, to vary from the system rated voltage by more than ±5%.

The values of the voltages will then range in the following intervals as specified in the Distribution Code:

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

Nominal Voltage	Lowest Voltage	Highest Voltage
220/127 V	209/120 V	231/134 V
380/220 V	360/209 V	400/231 V
400/230 V	380/218.5 V	420/241.5 V
13.8 kV	13.1 kV	14.5 kV
33 kV	31.4 kV	34.7 kV

6.9.8.2 Rapid voltage changes

Connection and disconnection of a Solar PV System from the distribution networks shall not give rise to voltage variations exceeding 3% of the system rated voltage at the Exit Point.

6.9.8.3 Harmonic and interharmonic voltages

Harmonic and interharmonic voltages at the Exit Point of a Solar PV System connected to the MV Distribution Network shall not exceed the limits of the planning levels specified hereinafter:

[10] Specifically, DPC2.4

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**	**1.8**
7	4.0	**9**	1.2	**4**	**1.0**
11	3.0	**15**	0.3	**6**	**0.5**
13	2.5	**21**	0.2	**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 = 6.5% for both 13.8 and 33kV voltage levels

For a Solar PV System connected to the MV Distribution Network, as suggested by IEC/TR 61000-3-6:2008 and commonly accepted

6.9.8.4 DC injection

Solar PV Systems shall not inject DC current into the network. The requirement is considered to be respected if the injected DC component is lower than 0.5% of the rated AC current value of the PV System.

The DC injection clause is considered to be passed when for all Solar PV Units within the Solar PV System the measured DC injection of a type-tested unit is below the above threshold.

The single Solar PV System shall be equipped with a DC fault detection system which disconnects the faulty unit when the above limit is exceeded. A valid alternative to such system is the use of an AC/AC transformer which prevents from any DC injection into the network.

6.9.8.5 Clusters of Single-phase / Two-phase Solar PV Inverters

The use of three-phase inverters is required. However, single phase inverters and two-phase inverters can used in combination to generate > 2 MW at the Exit Point. In such case, if multiple single-phase/two-phase inverters are used, these shall be equally distributed over the three phases in order to limit the overall imbalance of power between the phases; the maximum current imbalance between two phases shall be lower than 16A (3.52kW at 220Vac). Communication links between the single-phase / two-phase inverters may be used to ensure this requirement.

Any extension beyond the above stated power limits will be possible by using three-phase inverters, or by single-phase / two-phase inverters 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 whenever the above limit is exceeded.

6.10 Metering System

The metering system to be installed at Consumer Premises shall be in agreement with the requirements of WERA Regulations (Section 6), that is:

- a first digital meter (Main Meter) supplied and installed by SEC at the Exit Point, to measure both the energy injected into the Distribution Network and consumed from this one. For this reason, the meter must be bidirectional.

- a second digital meter (Solar PV System Meter) supplied and installed by SEC at the Exit Point only in case the Maximum Connected Capacity of the Solar PV exceeds 2MW.

The Main Meter measures the net energy at the Exit Point, whereas the Solar PV System Meter measures the energy produced by only the Solar PV System.

The Solar PV System Meter will be installed outside, close to the Main System Meter, until remote reading capability from SEC of this meter will be available. From that time on, Solar PV System Meters shall be installed within the Consumer Premises, as close as possible to Solar PV inverters.

7 COMPLIANCE

The Consumer shall ensure that its Solar PV System complies with the requirements defined in the present standards throughout the overall lifetime of the facility.

The Consumer shall notify to SEC any incident, failure or planned modification of its Solar PV System which may affect the compliance with the requirements defined in the present standards.

The Consumer shall provide SEC with all the documents, studies and measurements useful to demonstrate the compliance of its Solar PV System to the requirements defined in the present standards.

If deemed necessary, SEC shall have the right to request the Consumer to carry out additional tests or studies with the scope to demonstrate the compliance of the Solar PV System with the provisions of the present document. Such activities may be requested not only during the connection process, but at any time throughout the lifetime of the Solar PV System, and more specifically after any failures, modifications or replacements of any equipment that may have an impact on the compliance of the System with the present standards.

ANNEX A. CONNECTION SCHEMES

The schemes proposed in this Annex show as an example possible cases of connection of Solar PV Systems to MV Distribution Network of SEC, to summarize in single line diagrams the clauses on the connection as presented in this document, in particular in 6.2, 6.3 and 6.4. Different arrangements may be used if previously agreed with SEC.

These schemes have to be combined with the general scheme of the installation, for the feeding of the Consumer's loads.

The cases presented in the following are here listed:

Figure	Distribution Network (LV/MV)	Maximum Connected Capacity of the Solar PV System	Notes
1	MV	<2.5 MW	Multiple smaller Solar PV Units combined in the customer LV board and further connected LV/MV transformer (two winding) with external and unique Interface Protection. Interface Protection on the LV side. Backup Switch required.
2	MV	≥ 2.5MW and ≤ 5.4 MW	Two centralised Solar PV Units connected LV/MV transformer (three winding) with external and unique Interface Protection. Interface Protection on the MV side. Backup Switch required.
3	MV	≤ 5.4 MW and ≤ 25 MW	Higher plant capacity has multiple centralized Solar PV Units with external and unique Interface Protection. Interface Protection on the MV side. Backup Switch required.

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

LEGEND	
	SWITCH (CIRCUIT BREAKER OR CONTACTOR)
	CURRENT TRANSFORMER (CT)
	POTENTIAL TRANSFORMER (PT)
	LOAD
	INVERTER
	PHOTOVOLTAIC ARRAY
	POWER TRANSFORMER
	BIDIRECTIONAL ENERGY METER (4 QUADRANTS) - SMART METER

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

ANNEX B. DEFAULT SETTINGS OF INTERFACE PROTECTION

The following table reports the default settings to be implemented in the Interface Protection of Solar PV with > 2 MW Systems when no other settings have been communicated by SEC.

Table 5: Default settings for the protection functions of the IP

Protection function	Settings	
	Threshold	Time delay
27<	90% Nominal Voltage	1.5 s
27<<	40% Nominal Voltage	0.8 s
59>	110% Nominal Voltage	3 s
59>>	120% Nominal Voltage	0.2 s
81>>	62.5 Hz	0.1 s
81<	57.5 Hz	4 s
81<<	57 Hz	0.1 s

Table 6 LOM settings

Vector Shift (VS)	12 degrees	0.0s
Rate of Change of Frequency (RoCoF)	2.5 Hz per second	0.0s

NOTE: in case the interface protection is external, the built-in IP can either be excluded (if LOM is made externally) or higher settings.

ANNEX C. SERVICE AND ENVIRONMENTAL CONDITIONS

Usual service condition in the inland, desert or coastal areas environment in the Kingdom of Saudi Arabia as follows (amended to date) are listed hereinafter:

Altitude above mean sea level (msl):	a. up to 1000m (normal) b. above 1000m (as required)
Ambient Temperature (Outdoor):	Minimum: -5 °C Maximum: 55 °C Monthly average of the hottest month: 40 °C Yearly average: 30 °C
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%
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 (U.S. 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, and all metal parts shall be corrosion and/or abrasion resistant, and the degree or protection shall be at least IP54 as per IEC 60529 or equivalent NEMA Standard. The degree of protection for all indoor equipment shall be IP41 as per IEC 60529 or equivalent NEMA Standard.

ANNEX D. APPLICABLE STANDARDS FOR SOLAR PV > 2 MW SYSTEMS COMPONENTS

Along with the Technical Standards for the Connection described in the current document, all the components of Solar PV Systems shall comply with the applicable International and SASO standards which are listed in this Annex, according to the component they apply to.

This will ensure that components and equipment used in Solar PV systems in the Kingdom of Saudi Arabia fit with a minimum set of technical characteristics that give the necessary quality and avoid the use of unfit or unreliable material in Solar PV projects.

The list includes the standards issued by SASO at the time of publication of this document. However, standards may be subject to future revisions, amendments or extensions and it will be user's care to find the latest published versions and utilize them.

PV MODULES

- IEC 61215-1:2021 – Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 1: Test requirements.
- IEC 61215-1-1:2021 – Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 1-1: Special requirements for testing of crystalline silicon photovoltaic (PV) modules.
- IEC 61215-1-2:2021 – Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 1-2: Special requirements for testing of thin-film Cadmium Telluride (CdTe) based photovoltaic (PV) modules.
- IEC 61215-1-3:2021 – Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 1-3: Special requirements for testing of thin-film amorphous silicon based photovoltaic (PV) modules.
- IEC 61215-1-4:2021 – Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 1-4: Special requirements for testing of thin-film Cu (In, GA) (S, $Se)_2$ based photovoltaic (PV) modules.
- IEC 61215-2:2021 – Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 2: Test procedures.
- SASO IEC 61730-1:2017 – Photovoltaic (PV) module safety qualification - Part 1: Requirements for construction.
- SASO IEC 61730-2:2017 – Photovoltaic (PV) module safety qualification - Part 2: Requirements for testing.
- IEC 61701:2020 – Salt mist corrosion testing of photovoltaic (PV) modules.
- SASO IEC TS 62804-1:2017 – Photovoltaic (PV) modules - Test methods for the detection of potential-induced degradation - Part 1: Crystalline silicon.
- SASO IEC 62716:2016 – Photovoltaic (PV) modules - Ammonia corrosion testing.
- SASO IEC 62759-1:2015 – Photovoltaic (PV) modules - Transportation testing - Part 1: Transportation and shipping of module package units.
- IEC 62790:2020 – Junction boxes for photovoltaic modules - Safety requirements and tests.
- SASO IEC 62852:2015 – Connectors for DC-application in photovoltaic systems - Safety requirements and tests.
- SASO IEC 62979:2018 – Photovoltaic modules - Bypass diode - Thermal runaway test.

- IEC TS 62941:2019 – Terrestrial photovoltaic (PV) modules - Guideline for increased confidence in PV module design qualification and type approval.
- SASO IEC TS 62782:2017 – Photovoltaic (PV) modules - Cyclic (dynamic) mechanical load testing.
- IEC 60068-2-68:1994 – Environmental testing - Part 2-68: Tests - Test L: Dust and sand.

INVERTERS

- SASO IEC 62109-1:2017 – Safety of power converters for use in photovoltaic power systems - Part 1: General requirements.
- SASO IEC 62109-2:2012 – Safety of power converters for use in photovoltaic power systems - Part 2: Particular requirements for inverters.
- EN 50530:2010 – Overall efficiency of grid connected photovoltaic inverters.
- EN 50524:2009 – Data sheet and name plate for photovoltaic inverters.
- SASO IEC 62116:2017 – Utility-interconnected photovoltaic inverters - Test procedure of islanding prevention measures.
- IEC TS 62910:2020 – Utility-interconnected photovoltaic inverters - Test procedure for low voltage ride-through measurements.
- SASO IEC 62920:2018 – Photovoltaic power generating systems - EMC requirements and test methods for power conversion equipment.
- 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 61000-3-12:2011 – 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.

INTERFACE PROTECTIONS

- SASO IEC 62116:2017 – Utility-interconnected photovoltaic inverters – Test procedure of islanding prevention measures

SOLAR CABLES

- EN 50618:2014 – Electric cables for photovoltaic systems.
- SASO IEC 62930:2018 – Electric cables for photovoltaic systems with a voltage rating of 1.5 kV DC

PV STRING COMBINER BOXES

- EN 50178:1997 Electronic equipment for use in power installations.
- IEC 62477-1:2012+AMD1:2016 CSV Consolidated version – Safety requirements for power electronic converter systems and equipment - Part 1: General.
- IEC 62093:2021 – Photovoltaic system power conversion equipment - Design qualification and type approval.
- IEC 61439-2:2020 – Low-voltage switchgear and control gear assemblies - Part 2: Power switchgear and control gear assemblies.