EWA
هيئة الكهرباء والماء
Electricity & Water Authority
Kingdom of Bahrain

Technical Expert to develop grid connection guidelines and standards for the Kingdom of Bahrain

Standards for Distributed Solar PV Plants to be connected with the Distribution Network of the Kingdom of Bahrain

Version 1.3

October 2017

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1 SCOPE

This document provides a common set of requirements for solar PV (Photovoltaic) generating plants which intend to operate in parallel with the LV & MV distribution networks of the Kingdom of Bahrain. These requirements shall be fulfilled irrespective of the presence of loads in the customer's network. Especially the document defines:

- Requirements for the equipment to be used for the interconnection of a solar PV generating plant 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 the solar PV generating plants;
- Requirements to prevent the solar PV generating plants from causing disturbances and damages either to the distribution network and to the other customers connected to the same distribution network;
- Requirements to prevent the solar PV generating plants 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 incompatible with additional requirements set out by other national & international standards, network codes or specific technical requirements of EWA, and which may apply for the connection of a solar PV generating plant; especially, the document "Regulations for Electrical Installations" [1] is "*applicable to all electrical installations in any premises fed by the Electricity distribution system of the Kingdom of Bahrain*" as set out in [1] itself. Such document still represents the main technical document to refer to for the design of the electrical installation of a new customer or for the modification of the installation of an existing customer. The present standards shall apply only if the installation includes a solar PV generating plant and shall be intended as an extension of [1] only for what concerns the "active" part of the customer's network. For the "passive" part of the customer's network, reference shall be made to [1].

Moreover, it is not within the scope of the present document to:

- define the process to be followed for the selection and evaluation of the point of connection;
- define the process to be followed for the assessment of the impact of the connecting solar PV generating plant to the power system;
- define the process to be followed for the assessment of a connection application and its compliance with the present standards;
- define technical rules for the islanding operation of isolated networks, where no part of the distribution network is involved;

Unless otherwise explicitly specified, the requirements set forth by these standards shall apply only to solar PV generating plants which don't have already been approved by EWA at the date of publication of the standards.

Finally, even if it is not directly within the scope of the document, the present document intends to stress the fundamental importance and necessity for solar PV generating plants to be built in a workmanlike manner, which means the use of products and their assembly in accordance with the international standards commonly used for the planning, design, installation, operation and maintenance of solar PV generating plants. Some of the most relevant documents are listed in ANNEX C.

2 REFERENCE DOCUMENTS

[1] Regulations for electrical installations, Ministry of Electricity and Water, Electricity Distribution Directorate, Second edition, 2004
[2] IEC 62116:2014, Utility-interconnected photovoltaic inverters - Test procedure of islanding prevention measures
[3] IEC 61000-3-2:2014 Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)
[4] 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
[5] Bahrain Grid Code, Electricity and Water Authority, Kingdom of Bahrain, November 2011
[6] IEC/TR 61000-3-15: 2009, Assessment of low frequency electromagnetic immunity and emission requirements for dispersed generation systems in LV network

3 TERMS AND DEFINITIONS

Active Power - Active Power is the real component of the apparent power, expressed in watts or multiples thereof (e.g. kilowatts (kW) or megawatts (MW)). In the text this will be generically referred as P or Pn in case of rated active power of equipment.
Apparent Power - Is the product of voltage (in volts) and current (in amperes). It is usually expressed in kilovolt-amperes (kVA) or megavolt-amperes (MVA) and consists of a real component (Active Power) and an imaginary component (Reactive Power). In the text this will be generically referred as S or Sn in case of rated apparent power of equipment.
Maximum Available Active Power Output – Is the Active Power Output determined by the primary resource (for example, sun irradiance) and by the maximum steady-state efficiency of the generating plant for this operating point.
Current - Unless stated otherwise, current refers to the root-mean-square value of phase current.
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 - Is the medium or low voltage electricity grid for supplying electricity to the end consumers; for the scope of the present document and in accordance with international standards:

- A Low Voltage (LV) network is a distribution network with nominal voltage lower than 1kV AC or 1.5 kV DC. The LV network nominal voltage of the Kingdom of Bahrain is 400/230V.
- A Medium Voltage (MV) network is a network with nominal voltage included in the range from 1kV AC (1.5 kV DC) up to 35 kV. The MV network nominal voltage of the Kingdom of Bahrain is 11kV.

Generating plant - Is an indivisible set of installations which can generate electrical energy into the distribution network and is composed of generating units, circuits and auxiliary services.
Interface Protection (IP) - The electrical protection required to ensure that either the generating plant and/or any generating 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 conditions in which a distribution network, or part of it, is on purpose separated from the main power system with the final scope of de-energization.

Main electricity meter - Is the device installed at the POC and which measures the amount of electric energy actually exchanged by the customer with the distribution network.
Network - Plant and apparatus connected together in order to transmit or distribute electrical power, and operated by the DSO.
PV electricity meter - Is the device installed at the common output point of the solar PV generating plant and which measures the total energy produced from the solar PV generating units.
Point of Connection or POC - Is the location at which a solar PV generating plant is connected to the distribution network and where the main electricity meter is installed.
Power Factor - Is the ratio of Active Power to Apparent Power.
Reactive power capability – Defines the reserves of inductive/capacitive reactive power which can be provided by a generating plant/unit. The reactive power capability usually varies with the active power and the voltage of the generating plant/unit.
Reactive Power - Represents the imaginary component of the apparent power, usually expressed in kilovar (kVAr) or Megavar (MVAr).
ROCOF – Rate of change of frequency usually expressed in Hz/s.
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 – 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.
Voltage - Unless stated otherwise, voltage refers to the root-mean-square value of phase-to-phase voltages.

4 TECHNICAL REQUIREMENTS FOR THE CONNECTION IN PARALLEL TO THE DISTRIBUTION NETWORKS

4.1 General requirements

A solar PV generating plants shall be connected to the network at an appropriate point, called the POC. It is the responsibility of EWA to design a suitable process which determines the appropriate POC and assesses the capacity of the network to host the connecting solar PV generating plant at that POC whilst maintaining a safe and secure operation of the network for all operating conditions.

If the results of such process put in evidence that the connecting solar PV generating plant is likely to cause the network to possibly operate outside of EWA statutory performance standards, EWA has the right to turn down the connection application or to propose modifications (for example in terms of POC and/or characteristics of the solar PV generating plant) or alternative solutions (for example in terms of network reinforcements) to enable the connection.

With reference to the requirements defined in the present document and the possibility that different requirements may interfere with each other, the protection and control devices of a solar PV generating plant shall be organized in accordance with the following priority ranking (from highest to lowest):

1. Protection of the generating units;
2. Protection of the network (interface protection and protection against faults within the customer's network);
3. Remote disconnection;
4. Active power response to frequency variations;
5. Remote limitation of active power;
6. Remote reactive power control modes;
7. Local reactive power control modes.

4.2 Connection scheme

A solar PV generating plant shall be in compliance with the connection requirements of EWA; and especially shall meet the following requirements:

- the synchronization, operation and disconnection of the plant under normal network operating conditions, i.e. in the absence of faults or malfunctions, shall be done without consequences to the statutory power quality of the network;
- the protection schemes and settings needed for the solar PV generating plant shall be coordinated with the network protection schemes and settings; they shall therefore be agreed between EWA and the solar PV generating plant owner with the following scope:
    - faults and malfunctions within the solar PV generating plant shall not impair the normal operation of the distribution network,
    - the protection schemes and settings for internal electrical faults must not jeopardize the performances of the solar PV generating plant;
    - the protection schemes of the solar PV generating plant shall be coordinated with those of the distribution network in order to operate properly in case of faults within the generating plant or within the distribution networks.

In order to satisfy the above requirements, **Error! Reference source not found.** presents the typical equipment which shall be at least installed for a safe and reliable interconnection of the solar PV generating plant with the distribution network:

- The main switch shall be installed as close as possible to the POC and shall be commanded by a protection system against internal faults[1]; the main switch is also used for the disconnection of the customer's network from the distribution network; it is possible to install up to two main switches in order, for example, to have two separate circuits, one dedicated to the customer's loads and one dedicated to the solar PV generating plant.
- The interface switch shall be installed in the customer's network to separate from the distribution network the part(s) of the customer's network containing at least one solar PV generating unit; for a solar PV generating plant with a rated active power greater than 11kW, unless explicitly agreed by EWA, only one interface switch shall be used (see also §4.7.4).
- The unit switch shall be installed as electrically close as possible to the terminals of each solar PV generating unit of the generating plant, for the protection and the disconnection of that generating unit.

ANNEX A presents typical connection schemes which can be adopted for the connection of a solar PV generating plant to EWA distribution networks. Different arrangements may be used if previously agreed with EWA.

For each of the above mentioned equipment, the choice of the type of switch to be installed (power relays, contactors or mechanical circuit breakers, …) shall be based on:

- the functions the switch shall carry out,
- the characteristics of the customer's network.

Especially, the following criteria shall be adopted:

- the main switch shall be compliant with the requirements of [1][2],
- the switch(es) of the generating unit(s) shall be compliant with the manufacturer's requirements,
- Electronic switches shall not be used for protective functions.
- For solar PV generating plants connected to the MV distribution network and with the interface switch on the MV side of the plant (Figure 8), the interface switch shall consist of:
    - three-polar withdrawable automatic circuit breaker operated by an undervoltage release, or
    - three-polar automatic circuit breaker operated by an undervoltage release along with an isolator (either upstream or downstream the circuit breaker).
- For solar PV generating plants connected to the MV distribution network and with the interface switch on the LV side of the plant or for solar PV generating plants connected to the LV distribution network, the interface switch shall consist of:
    - automatic circuit breaker or switch disconnector operated by an undervoltage release, or
    - omnipolar AC3 contactor.
- any switch shall have a breaking and making capacity coordinated with the rated values of the customer's network, taking into consideration both the generating plant and the passive loads.
- the short-time withstand current of the switching devices shall be coordinated with the maximum short circuit power at the POC[3].

[1] For the definition of the requirements of the protection system against faults within the customers' network, please refer to [1]

[2] With particular reference to section 5 "EXCESS CURRENT PROTECTION"

- In case of loss of auxiliary supply power to the switchgear, a secure disconnection of the switch is required immediately.

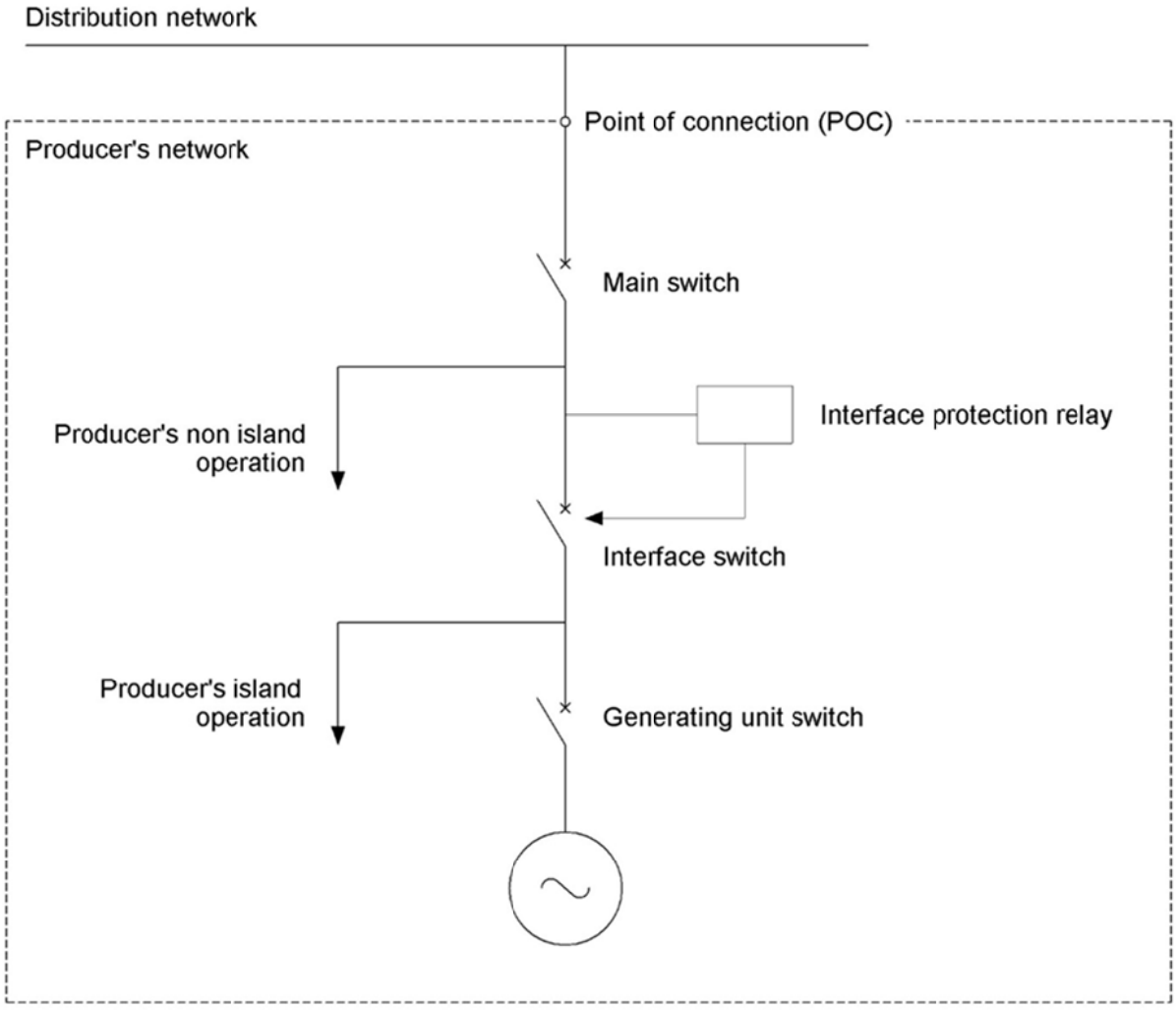

Figure 1: Schematic representation for the interconnection of a solar PV generating plant with the distribution network of the Kingdom of Bahrain

The function of the interface switch might be combined with either the main switch or the generator switch in a single switching device[4]. In case of a combination, the single switching device shall be compliant with the requirements of both, the interface switch and the combined switch (main switch or generator switch). As a consequence, at least two switches in series shall be always present between a solar PV generating unit and the POC.

[3] Information about the maximum prospective short-circuit level of the Bahraini distribution networks are reported in the regulation Nr 303 of [1].

[4] 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, which means that the power supply will be removed also to the customer's loads, if any.

4.3 Normal operating ranges

Solar PV generating plants, when generating power, shall have the capability to operate stably and continuously in the operating ranges specified below, regardless the topology and the settings of the protection systems:

- when the frequency at the POC stays within the range 47,5Hz to 52,5Hz.
- when the voltage at the POC stays within the range 90% to 110% of the rated voltage.

4.4 Immunity to disturbances

4.4.1 Low Voltage Ride Through (LVRT) capability

Solar PV generating plants shall contribute to overall power system stability by providing also immunity towards dynamic voltage changes, especially those due to secure faults on the higher voltage level networks. The requirements below apply to all kinds of disturbances (1ph, 2ph and 3ph) and are independent of the interface protection settings (see § 4.7.4) which overrule the technical capabilities of a generating plant.

A solar PV generating plant with a rated active power greater than 11kW shall be capable to stay connected to the distribution network as long as the voltage at the POC remains above the voltage-time diagram of Figure 2. The p.u. voltage shall be calculated with respect to the nominal voltage at POC. For three-phase generating plants, 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 generating plant.

After the faults is cleared and the voltage returned within the voltage normal operating range, 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 generating pant rated power.

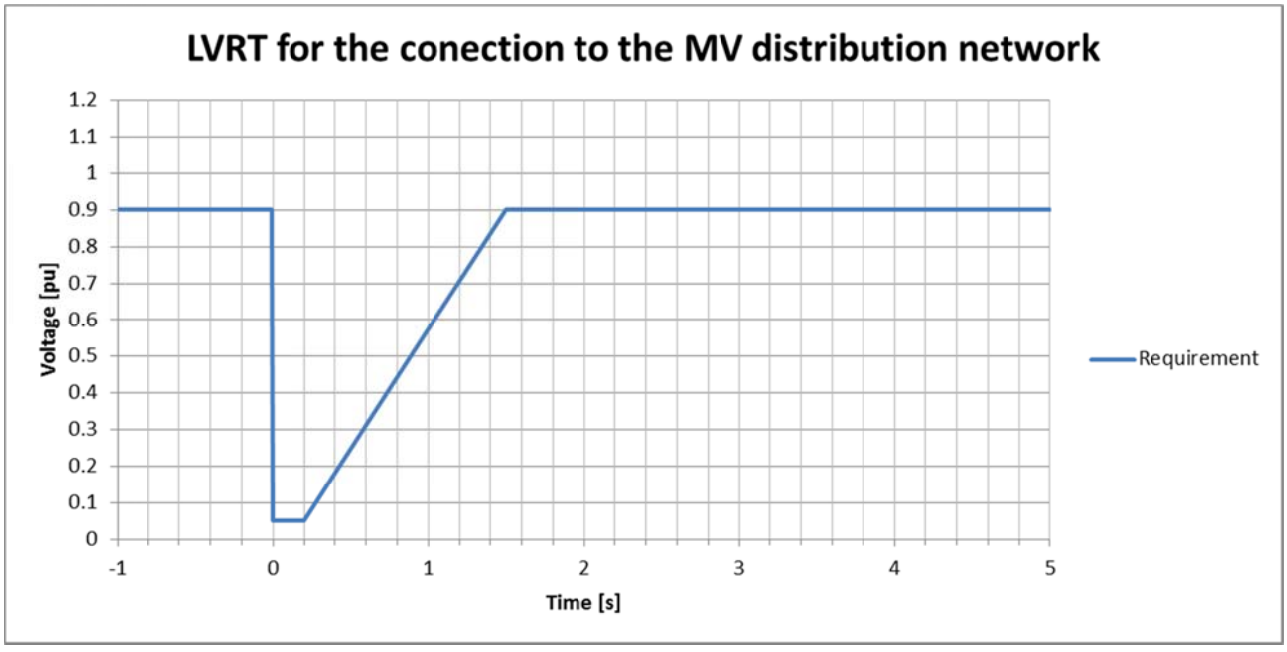

Figure 2: LVRT characteristic for solar PV generating plant

4.4.2 ROCOF withstand capability

Solar PV generating plants, when generating power, shall be able to go through frequency transients with frequency within the frequency normal operating range (§4.3) and with ROCOF value up to 2 Hz/s.

4.5 Requirements for the frequency stability of the power system

4.5.1 Active power response to frequency variations

A solar PV generating plant shall be capable of activating the provision of active power response to over-frequency transients according to the curve of Figure 3[5], with frequency threshold and droop settings adjustable and to be specified by EWA;

- the frequency threshold shall be settable at least between 50 Hz and 52 Hz inclusive; if not explicitly specified by EWA, the threshold shall be set to 50,3Hz;
- the droop settings shall be between 2% and 12%; if not explicitly specified by EWA, the droop shall be set to 4,4%;
- the pu active power shall be referred to the actual active power value when the threshold is reached and the active power response is activated.

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.

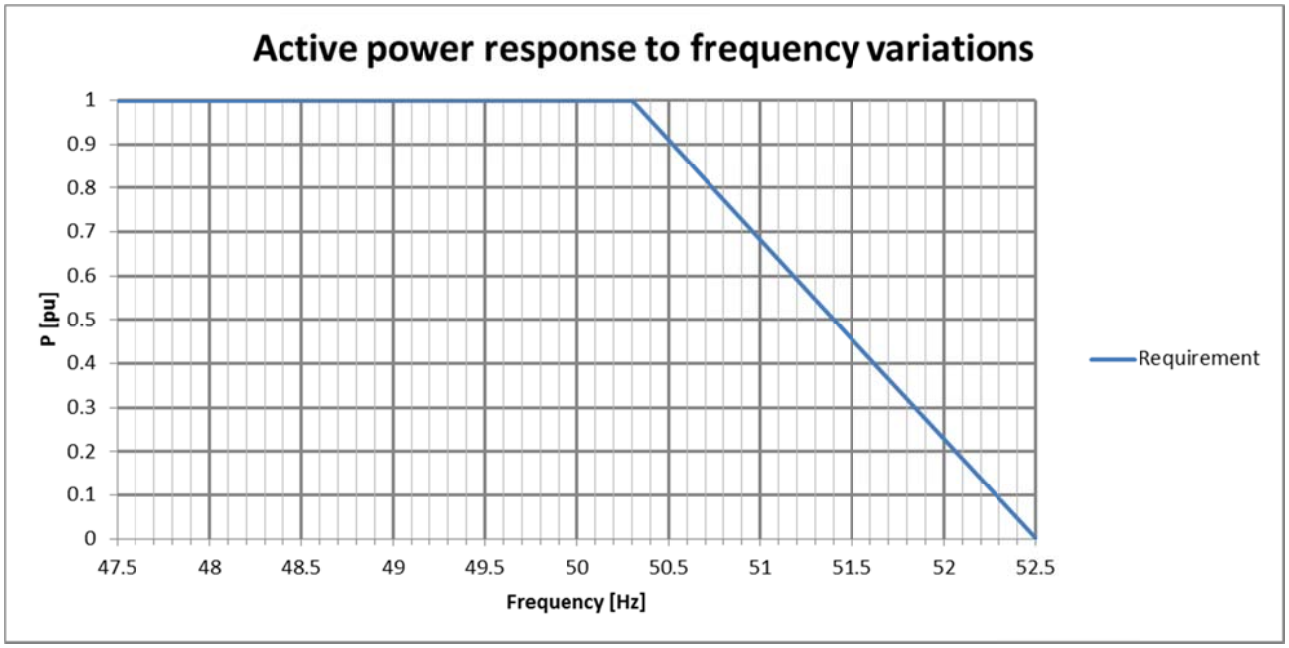

Figure 3: Active power frequency response for solar PV generating plant

4.5.2 Active power delivery at under-frequencies

A solar PV generating plant shall be resilient to reductions of frequency at the POC, limiting as low as possible the reduction of its maximum active power due to under-frequency operating conditions.

[5] In the figure, the power 1 p.u. refers to the actual output power at the time the frequency threshold is reached.

4.5.3 Remote limitation of active power

A solar PV generating plant with a rated active power greater than or equal to 11kW 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 Pn.

In accordance with the provisions set forth in §4.7.5, EWA 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 generating units connected to its network.

4.6 Requirements for the voltage stability of the power system

4.6.1 Reactive power capability

When voltage and frequency at POC are within their normal operating ranges, a solar PV generating plant shall be able to provide reactive power in any operating point within the boundaries of the reactive power capability defined in Figure 4[6].

[6] The active power 1 p.u. shall refer to the rated active power value of the solar PV generating plant: at 1 p.u. of active power, the reactive power capability of a solar PV generating plant corresponds to a power factor varying between 0,9 leading to 0.9 lagging.

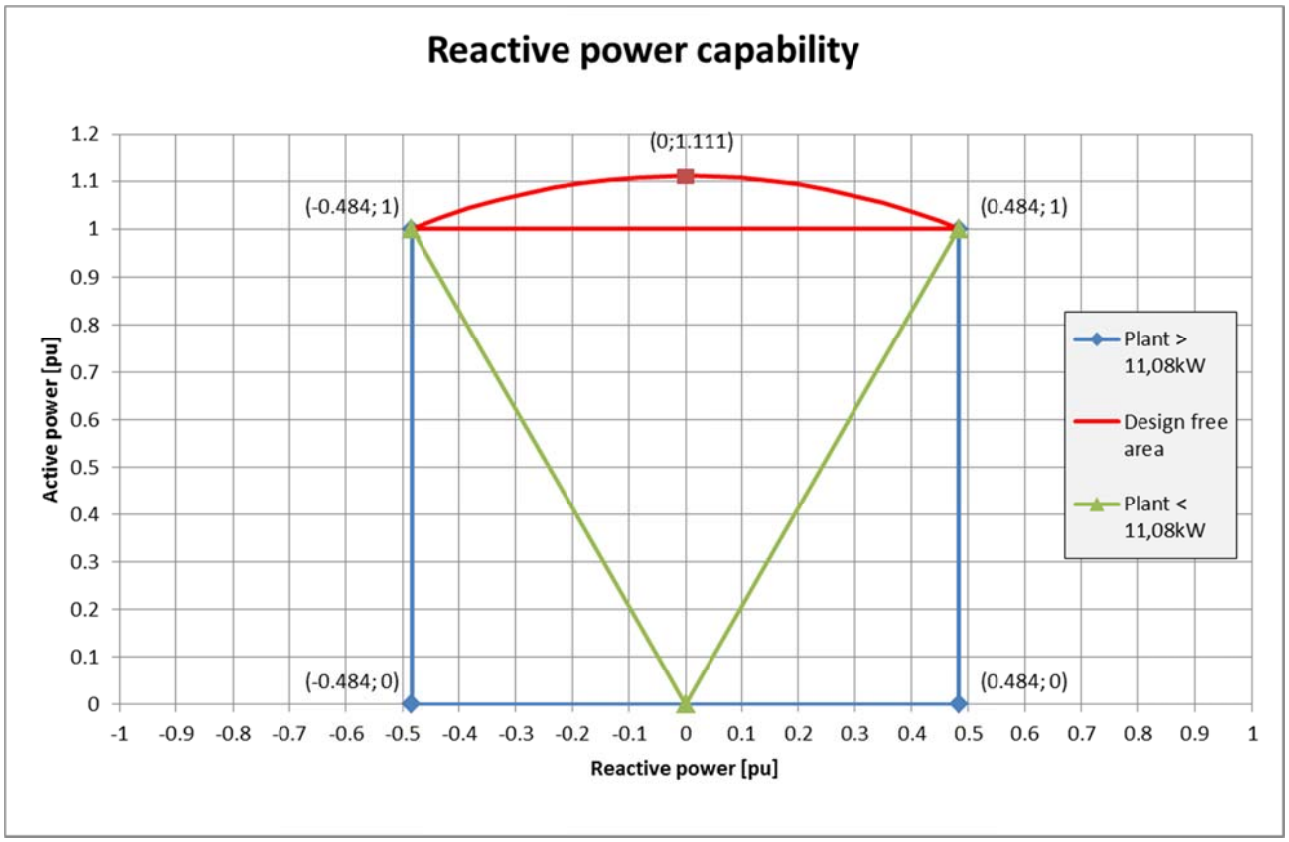

Figure 4: Reactive power capability

With reference to Figure 4, when the solar PV generating plant operates in the design free area (i.e. above its rated 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 generating units.

When the solar PV generating plant is operating above a threshold of 10 % of its nominal apparent power Sn, the required reactive power 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.

4.6.2 Reactive power control modes

A solar PV generating plant shall be capable of operating in the control modes stated below, within the limits of its reactive power capability:

- Q fix : the reactive power is controlled in order to have a fix value ;
- Cos φ fix : the reactive power is controlled in order to have a fix power factor;
- Cos φ (P) : the reactive power is controlled in order to have a power factor function of the actual active power delivery;

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.

4.6.2.1 Fix control modes

When operated with Q fix or cos φ fix control mode, the solar PV generating 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 generating plant.

For a solar PV generating plant with a rated active power greater than or equal to 11kW, the solar PV generating plant shall also be able to receive the set-point from a remote control center in accordance with the provisions set forth in §4.7.5.

4.6.2.2 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 5 shall be configurable within the control systems of the solar PV generating plant; a change in active power output results in a new cos φ set point according to the characteristic.

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

- A P = 0 Pncos φ = 1
- B P = 0,5 Pn cos φ = 1
- C P = Pn cos φ = 0.9 (with the solar PV generating plant absorbing reactive power)

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 according to the requirements of §4.6.1.

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 POC: the contribution is activated when the voltage at POC exceeds the lock-in voltage and is deactivated when the voltage at POC drops below the lock-out voltage. When the contribution is not activated, the solar PV generating plant shall be controlled with a unit power factor.

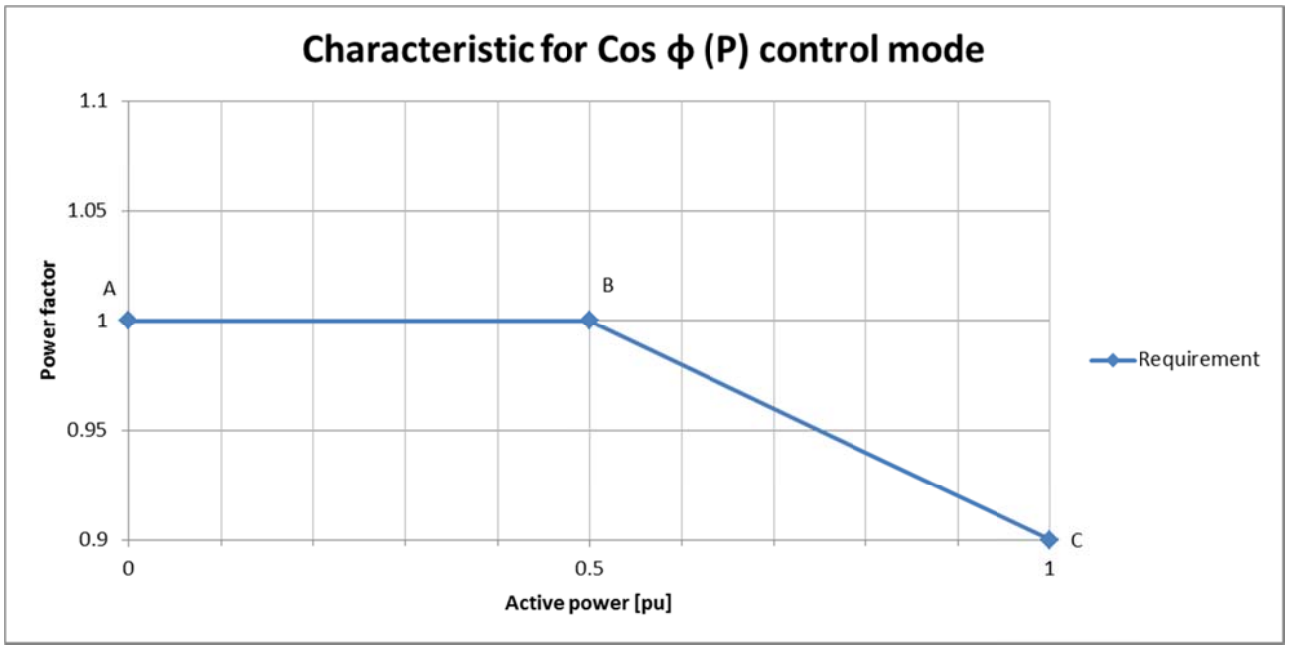

Figure 5: Characteristic for Cos φ (P) control mode

4.6.3 Power reduction at increasing voltage

In order to avoid the disconnection due to overvoltage protection, a solar PV generating plant is allowed to reduce its power output (active and/or reactive power) as a function of the rising voltage at POC. The implemented logic can be chosen by the manufacturer/customer. Nevertheless, the implemented logic shall not cause steps or oscillations in the power output.

4.6.4 Reactive current injection during a fault

The provision of reactive current during a fault is currently not required for solar PV generating plants. Such feature might be introduced in the future in a scenario of a growing penetration level of distributed generation and a decreasing short circuit power of the power system of the Kingdom of Bahrain.

4.7 Requirements for the management of the power system

4.7.1 Connection conditions

A solar PV generating plant is allowed to connect 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 47,5 Hz ≤ f ≤ 50,05 Hz;
- Voltage range 94% Uc ≤ U ≤ 106% Uc;
- Minimum observation time 180s.

Synchronizing a solar PV generating plant with the distribution network shall be fully automatic i.e. it shall not be possible to manually close the switch between the two systems to carry out synchronization[7].

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

The synchronization of a solar PV generating plant to the distribution network shall not create transient voltage variation at the POC of more than 3% of rated voltage.

After connection, a solar PV generating plant shall follow its target active power value with a variation rate not greater than 10% P_n/min.

The active power target shall be the maximum available active power output which is possible to generate from the solar PV generating plant, 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 §4.5.1, 4.5.3 and 4.6.3).

4.7.2 Remote disconnection

A solar PV generating plant with a rated active power greater than or equal to 11kW 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 §4.7.5, EWA 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 generating plants connected to its network.

4.7.3 Automatic reconnection after tripping

After the trip of the interface protection, a solar PV generating plant 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 47,5 Hz ≤ f ≤ 50,05 Hz;
- Voltage range 94% Uc ≤ U ≤ 106% Uc;
- Minimum observation time 180s.

After reconnection, the solar PV generating plant shall return to its target active power value with a variation rate not greater than 10% P_n/min.

4.7.4 Interface Protection

The purpose of the interface protection is to:

- disconnect the solar PV generating plant from the distribution network in the following cases
  - EWA switches off the distribution network (or the feeder) the generating plant is connected to (i.e. to prevent unintentional islanding);
  - Voltage or frequency transients of the power system out of the normal operating ranges as defined in §4.3.
- prevent the solar PV generating plant, when generating power, to cause overvoltages in the distribution network it is connected to;

It is not the purpose of the interface protection to:

- disconnect the generating plant from the distribution network in case of faults within the customer's network; for such issues, the requirements for the connection of passive customers shall apply [1][8];

[8] Especially Section 5 "EXCESS CURRENT PROTECTION"

- prevent damages to the customer's equipment (generating units or loads) due to faults/incidents (e.g. short circuits) on the distribution network or on the customer's internal network; for such issues, the recommendations and requirements of the manufacturers of the equipment shall apply.

In any case, the protection schemes and settings for electrical faults within the customer's network as well as those used for the protection of the customer's equipment must not jeopardise the performances of the requirements set out at §4.4 (immunity).

The interface protection shall be a dedicated device which acts on the interface switch. For a solar PV generating plant with a rated active power lower than 11kW, it is permitted to integrate the interface protection into the solar PV generating units.

The interface protection shall command the interface switch; for a solar PV generating plant with a rated active power greater than 11kW, unless explicitly agreed by EWA, only one interface protection and one interface switch shall be used for a solar PV generating plant.

For a solar PV generating plant with a rated active power greater than 20kW, 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[9]. When the back-up switch is triggered because the interface switch had failed to open, only manual reclosure shall be possible[10].

For a solar PV generating plant with a rated active power greater than 11kW, the power supply of the interface protection shall include an uninterruptible power supply.

The loss of the auxiliary voltage of either the interface protection or the solar PV generating plant'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 POC nominal voltage 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 POC nominal voltage adjustable by steps of 5%, and delay time in the range [0,1s;5s] adjustable in steps of 0,05s.
- Overvoltage 10 min mean [59-Av][11]
  - One threshold in the range [100%; 115%] of the POC nominal voltage adjustable by steps of 1%, and delay time lower than or equal to 3s;
- Overvoltage [59]
  - One threshold [59>] in the range [100%; 120%] of the POC nominal voltage adjustable by steps of 1%, and delay time in the range [0,1s;100s] adjustable in steps of 0,1s;

[9] 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.

[10] 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.

[11] voltage protection function using the 10 minutes r.m.s. voltage as input

  - One threshold [59>>] in the range [100%; 130%] of the POC nominal voltage 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 [50Hz; 53Hz] 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 [50Hz; 53Hz] 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 [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;
- Loss Of Mains:

  for the LOM protection functions, 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 but only some of these methods rely on standards. The present document doesn't 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 [2] (or other equivalent standards) which provides procedures to evaluate the performance of islanding prevention measures used with utility-interconnected PV systems.

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

The protection functions for undervoltage [27] and overvoltage [59] shall be fed by all the line voltages with at least one solar PV generating unit, whereas the protection functions for underfrequency [81<] and overfrequency [81>] shall be fed by at least one line voltages.

EWA is responsible to define the appropriate settings to be applied to the interface protection and which can ensure the correct tripping of the solar PV generating plant under specific conditions. The settings are chosen so that, in case a fault within the distribution network triggers the network protection systems (which in turn disconnect the faulty feeder), there could not be any reclosure of the network switch before all the solar PV generating plants have been disconnected.

ANNEX B proposes default settings for the different protection functions. Such settings shall be actually applied in the IP of a solar PV generating plant only in case no settings have been explicitly specified and communicated by EWA.

The interface protection shall have at least two configurable digital inputs which may be used in the future[12] by EWA 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.

[12] In a scenario of growing penetration level of distributed generation in the distribution networks of the Kingdom of Bahrain

4.7.5 Monitoring, remote control and information exchange

Adequate information concerning the customers connected to the distribution networks is a prerequisite for enabling EWA to maintain the stability and security of its networks. EWA needs to have a continuous overview of the state of its network, which may require, in some cases, updated information on the operating conditions of the solar PV generating plants 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 generating plants 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.

A solar PV generating plant with a rated capacity greater than 11kW[13] shall therefore be equipped with a bi-directional communication interface which can be used for the exchange of information with EWA. Once actually needed for the operation of the network, in accordance with a cost/benefit approach, EWA shall have the right to specify additional requirements concerning especially:

- Data, which shall be collected and sent to EWA in real-time or periodically, related to the operating conditions of the solar PV generating plant;
- Operational instruction sent by EWA which shall be executed by the solar PV generating plant; such instructions shall be compliant with the requirements indicated in the present standards (especially the requirements of §4.5.3 and §4.7.2);
- Communications channels and protocols to be used for the above requirements.

If technically possible, EWA 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.

4.7.6 Power quality

4.7.6.1 Voltage deviation

Under normal operating conditions, the connection and operation of a solar PV generating plant shall not cause the voltage at its POC and at the POC of any other customer connected to the same distribution network, to vary from the system rated voltage by more than ±6%.

4.7.6.2 Rapid voltage changes

Connection and disconnection of a solar PV generating plant from the distribution networks shall not give rise to voltage variations exceeding 3% of the system rated voltage at the POC.

4.7.6.3 Harmonics and inter-harmonics

Voltage harmonics and inter-harmonics at the POC of a solar PV generating plant shall not exceed the limits specified below.

Voltage level (Volts)	Total harmonic voltage distortion (%)	Individual harmonic voltage distortion (%)	
		Odd	Even
400/230	5	4 for n < 14 1.5 for n ≥ 14	2
11000 V	4	3	1.75

Moreover, the customer shall be required to make provision for the possible future installation of compensating apparatus if the solar PV generating plant generates

- odd harmonics exceeding 1% voltage distortion or
- even harmonics exceeding 0.6%, or
- the contribution of the solar PV generating plant to the THD at the POC exceeds 1.6%.

For a solar PV generating plant connected to an LV distribution network, it is commonly accepted [6] that the above mentioned requirements concerning the voltage harmonics are fulfilled if the harmonic current emissions of the solar PV generating plant don't exceed the following limits:

- for generating plants with a rated active power below 600W, the limits defined in the standard IEC 61000-3-2 [3], Class C (lighting) equipment, shall apply;
- for power plant with a rated active power greater than 600W, the limits defined in the standard IEC 61000-3-12 [4], Table 2, R_{sce} = 33,.shall apply.

4.7.6.4 DC injection

The DC component which solar PV generating plants inject into the network shall not exceed 0,5% of the rated AC current value of the plant.

The single solar PV generating plant 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.

4.7.6.5 Clusters of single-phase generating units

The use of three-phase equipment is required. In accordance with [1][14], it is anyway allowed for a solar PV generating plant with a rated active power lower than 20kW to be composed of one or more single-phase generating units. In such case, if the supply from EWA is a three-phase service and if multiple single-phase units are used, the single-phase generating units shall be equally distributed over the three phases in order to limit the overall imbalance of current between the phases[15].

4.8 Metering

Dedicated metering systems are required for solar PV generating plants.

[14] Especially, rule nr 404 of [1]

[15] If feasible, a maximum imbalance of 16A between the phases is recommended.

As a general rule. the metering positions and the meters used for metering solar PV generating plants shall be in accordance with section 4 of [1].

In partial derogation from regulation Nr 401 of [1], a customer with a solar PV generating plant shall have two metering positions:

- A net-metering position where the main electricity meter is installed,
- A solar PV production metering position where the PV electricity meter is installed.

The main electricity meter measures the net energy at the POC whereas the PV electricity meter measures the energy produced by the solar PV generating plant connected to the POC.

In derogation from regulation Nr 418 of [1], the PV electricity meter can be installed within the customer's premises; in such case, the PV electricity meter shall have remote meter reading capability.

5 COMPLIANCE

A customer shall ensure that its solar PV generating plant complies with the requirements defined in the present standards throughout the overall lifetime of the facility.

The customer shall notify to EWA any incident, failure or planned modification of its solar PV generating plant which may affect the compliance with the requirements defined in the present standards.

The customer shall provide EWA with all the documents, studies and measurements useful to demonstrate the compliance of the solar PV generating plant to the requirements defined in the present standards.

If deemed necessary, EWA shall have the right to request the customer to carry out additional tests or studies with the scope to demonstrate the compliance of the solar PV generating plant 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 generating plant, and more specifically after any failure, modification or replacement of any equipment that may have an impact on the compliance of the plant with the present standards.

When studies are required, EWA shall provide the customer with all the technical data of the network necessary to carry out the studies.

ANNEX A. CONNECTION SCHEMES

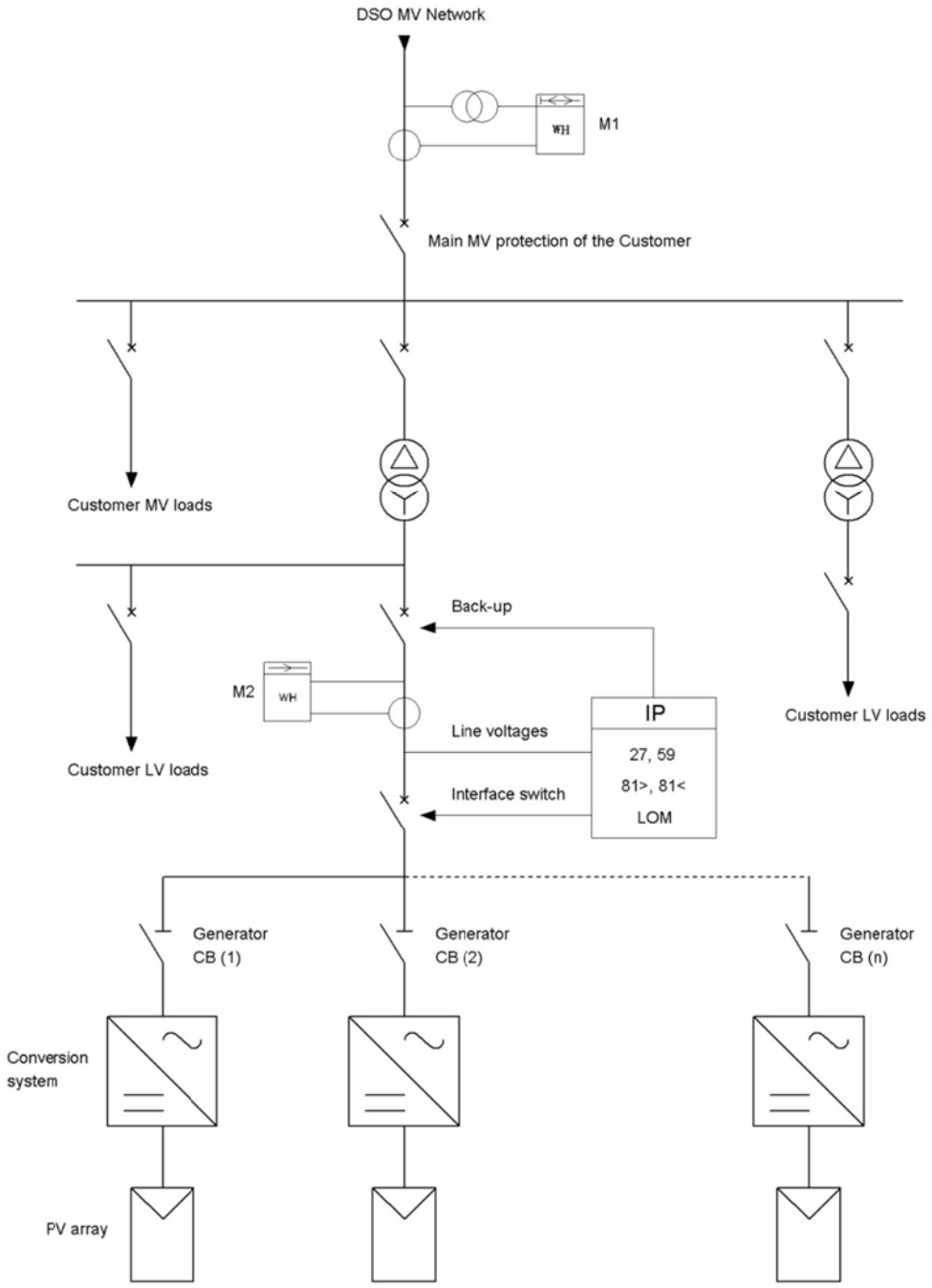

Figure 6: MV connection scheme – Interface switch on LV side

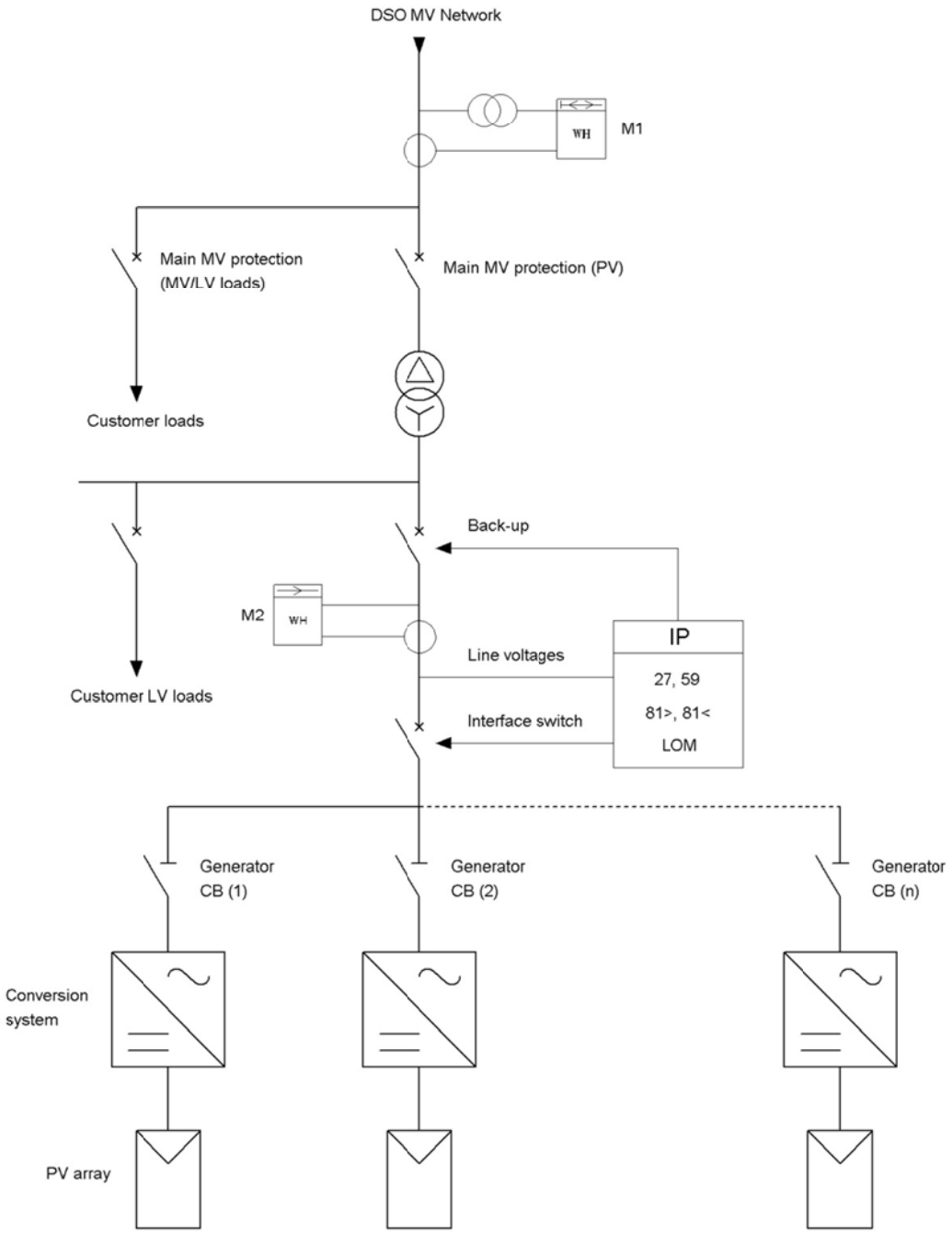

Figure 7: MV connection scheme – Two main switches

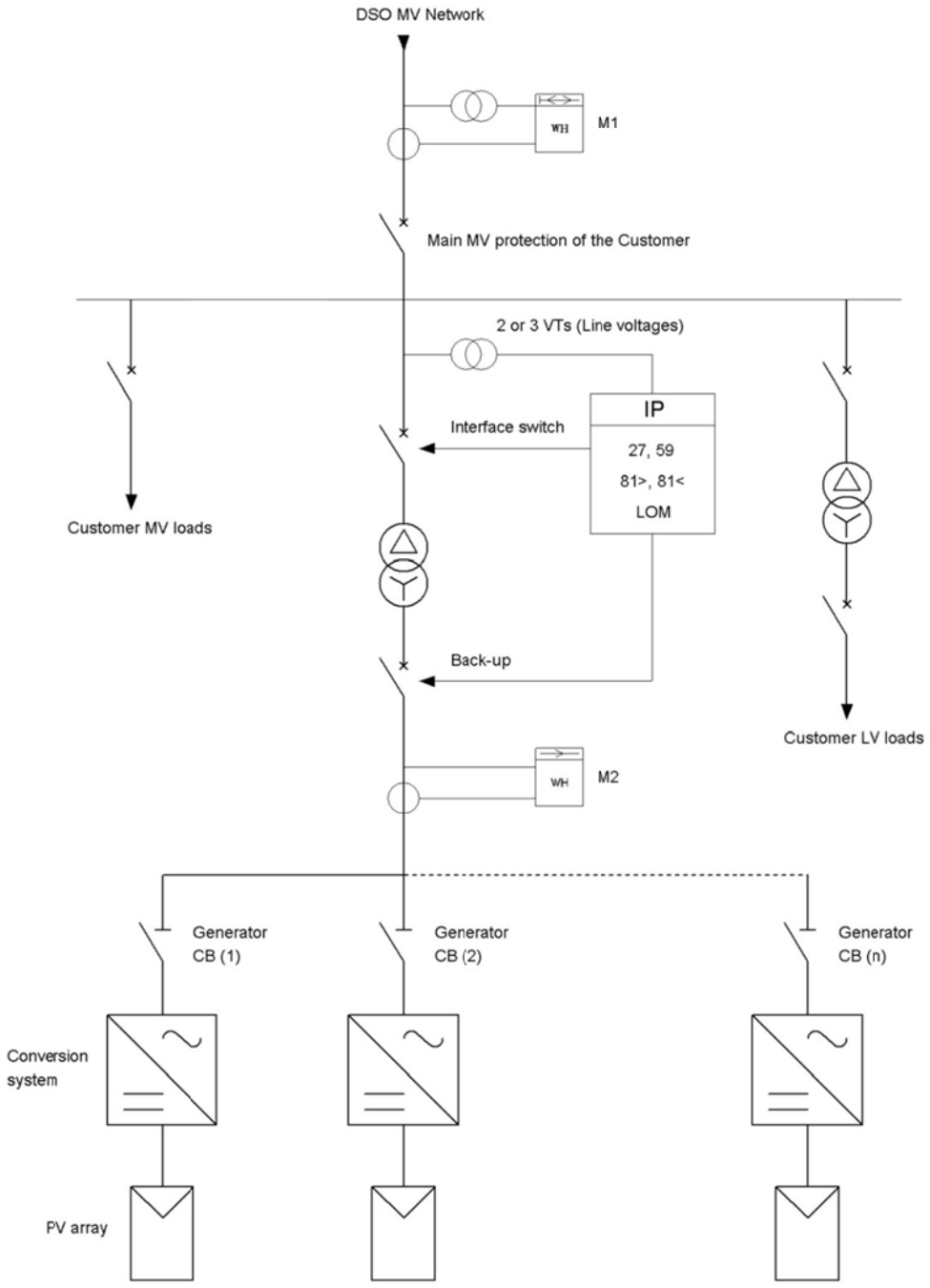

Figure 8: MV connection scheme – Interface Switch on MV side

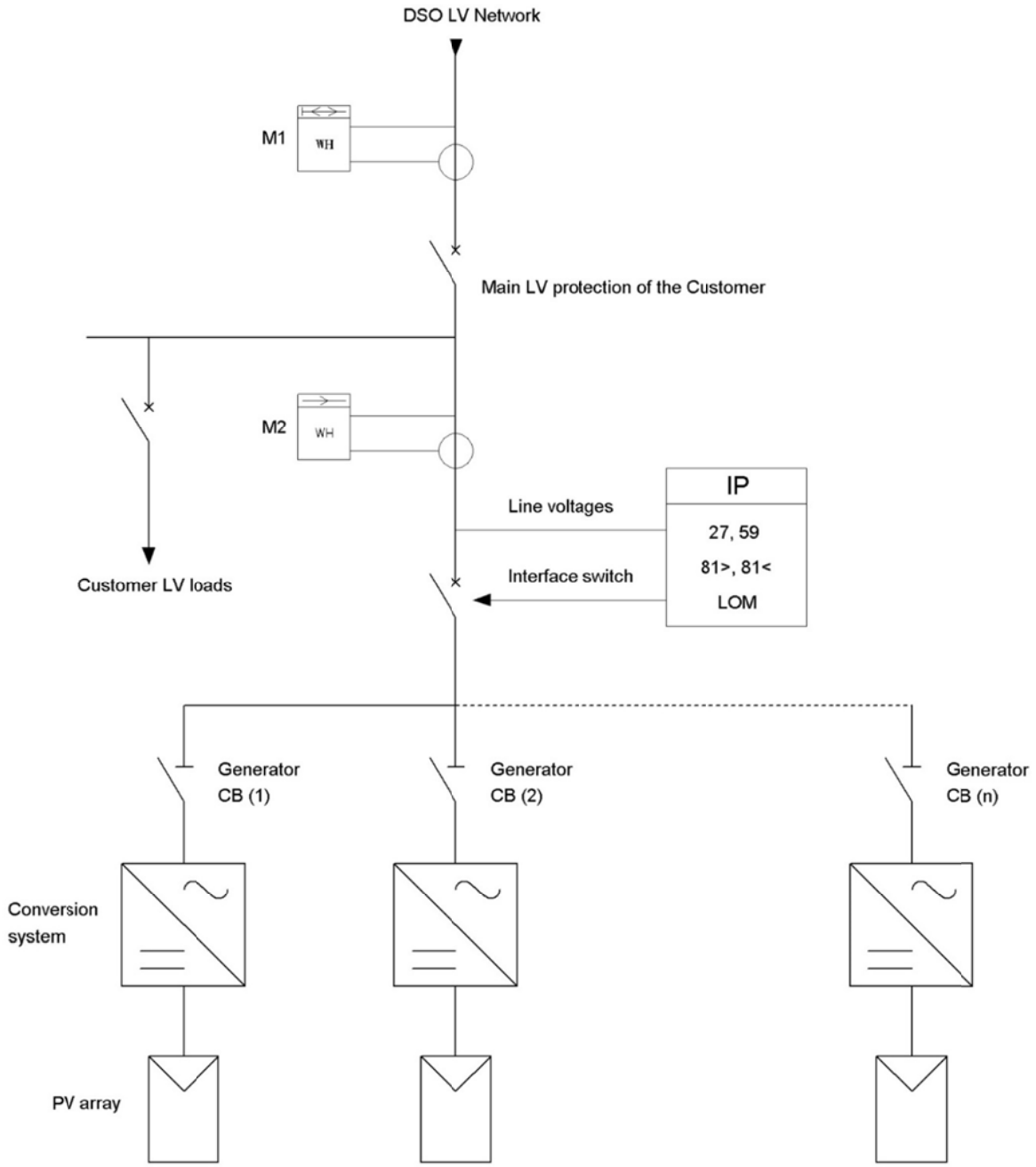

Figure 9: LV Connection Scheme

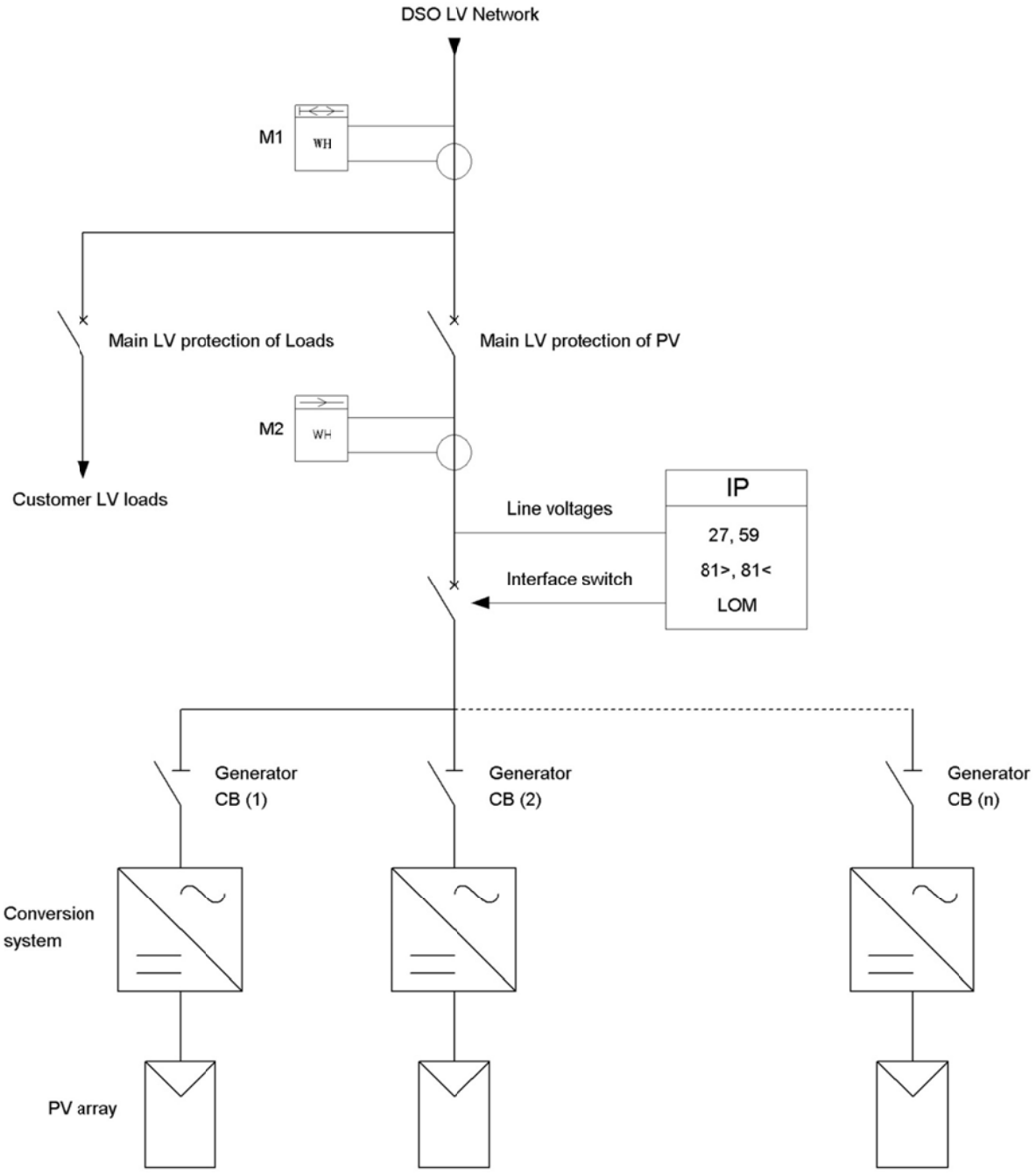

Figure 10: LV connection scheme – Two main switches

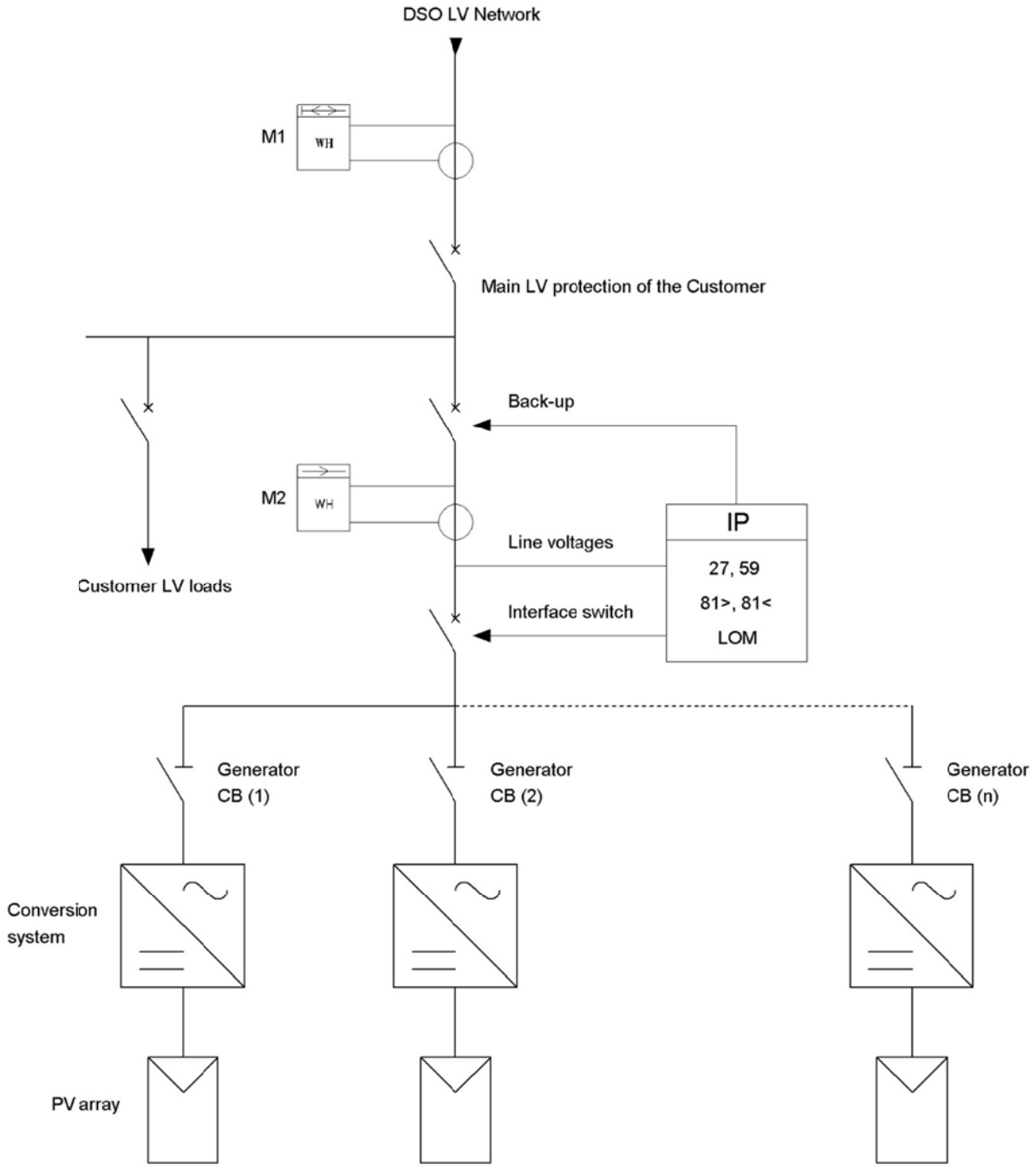

Figure 11: LV connection scheme with back-up

ANNEX B. DEFAULT SETTINGS OF INTERFACE PROTECTION

The following Table 1 reports the default settings to be implemented in the interface protection of solar PV generating plants when no other settings have been communicated by EWA.

Table 1: Default settings for the protection functions of the IP

Protection function	LV network		MV network	
	Threshold	Time delay	Threshold	Time delay
27<	90%	0.4 s	90%	1.5 s
27<<	40%	0.2 s	30%	0.2 s
59>	110%	1.5 s	110%	1.5 s
59>>	120%	0.2 s	120%	0.2 s
81>>	52.5 Hz	0.1 s	52.5 Hz	0.1 s
81<	47.5 Hz	4 s	47.5 Hz	4 s
81<<	46.5 Hz	0.1 s	46.5 Hz	0.1 s

ANNEX C. LIST OF APPLICABLE STANDARDS FOR EQUIPMENT

The main standards to be used as a reference in the development of a solar PV application are summarized hereinafter. For each standard a short comment and its relevancy (a 3-level scale is adopted) are proposed with the following legend:

☆ Useful document
☆☆ Important document
☆☆☆ Fundamental document

A.1. PV modules

Reference	Title	Relevancy	Application
IEC 61215-1	Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 1: Test requirements	☆☆☆	All PV modules, type tests
IEC 61215-1-1	Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 1-1: Special requirements for testing of crystalline silicon photovoltaic (PV) modules	☆☆☆	All crystalline PV modules, special requirements
IEC 61215-1-2	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	☆☆☆	All CdTe PV modules, special requirements
IEC 61215-1-3	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	☆☆☆	All amorphous silicon PV modules, special requirements
IEC 61215-1-4	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	☆☆☆	All Cu(In,GA)(S,Se)2 PV modules, special requirements
IEC 61215-2	Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 2: Test procedures	☆☆☆	All PV modules, type tests
IEC 61730-1	Photovoltaic (PV) module safety qualification - Part 1: Requirements for construction	☆☆☆	All PV modules, especially those installed on buildings, construction
IEC 61730-2	Photovoltaic (PV) module safety qualification - Part 2: Requirements for testing	☆☆☆	All PV modules, especially those installed on buildings, testing
IEC 61701	Salt mist corrosion testing of photovoltaic (PV) modules	☆☆☆	PV modules installed in a marine environment
IEC 62716	Photovoltaic (PV) modules - Ammonia corrosion testing	☆☆	Tests on PV modules used in environments with a high degree of ammonia
IEC 62759-1	Photovoltaic (PV) modules - Transportation testing - Part 1: Transportation and shipping of module package units	☆☆	Tests on all PV modules to assess the mechanical stress during transportation
IEC TS 62782	Photovoltaic (PV) modules – Cyclic (dynamic) mechanical load testing	☆☆	Tests on PV modules used in environments with a high mechanical stress
IEC 62790	Junction boxes for photovoltaic modules – Safety	☆☆	Tests on the junction boxes

Reference	Title	Relevancy	Application
	requirements and tests		of all PV modules
IEC TS 62804-1	Photovoltaic (PV) modules - Test methods for the detection of potential-induced degradation - Part 1: Crystalline silicon	☆☆	Tests on all PV modules to prevent the occurrence of PID
IEC TS 62941	Terrestrial photovoltaic (PV) modules - Guideline for increased confidence in PV module design qualification and type approval	☆☆	Performance and reliability of certified PV modules
IEC 62979	Photovoltaic modules - Bypass diode - Thermal runaway test.	☆☆	evaluate if bypass diode can have thermal runaway
EN 50380	Datasheet and nameplate information for photovoltaic modules	☆☆	Documentation for PV modules
IEC 60068-2-68	Environmental testing - Part 2-68: Tests - Test L: Dust and sand	☆☆☆	Environmental test applied to PV modules installed in desert climates

A.2. Inverters

Reference	Title	Relevancy	Application
IEC 62109-1	Safety of power converters for use in photovoltaic power systems - Part 1: General requirements	☆☆☆	Safety requirements for inverters, international standards
IEC 62109-2	Safety of power converters for use in photovoltaic power systems - Part 2: Particular requirements for inverters	☆☆☆	
IEC 62116	Utility-interconnected photovoltaic inverters - Test procedure of islanding prevention measures	☆☆☆	Test methods for assessing the capacity of an inverter and its protection to avoid islanding
IEC TS 62910	Utility-interconnected photovoltaic inverters - Test procedure for low voltage ride- through measurements	☆☆☆	Test methods for assessing the LVRT capacity of inverters
IEC 62920	Photovoltaic power generating systems - EMC requirements and test methods for power conversion equipment.	☆☆☆	EMC requirements for inverters used in PV systems
EN 50524	Data sheet and name plate for photovoltaic inverters This European Standard describes data sheet and name plate information for photovoltaic inverters in grid parallel operation	☆	Documentation for inverters
EN 50530	Overall efficiency of grid connected photovoltaic inverters	☆☆	Test methods for measuring static and dynamic efficiency of PV inverters

A.3. EMC (Electro Magnetic Compatibility)

Reference	Title	Relevancy	Application
IEC 61000-3-2	Electromagnetic compatibility (EMC) - Part 3-2: Limits - Limits for harmonic current emissions (equipment input current ≤16 A per phase)	☆☆☆	Maximum output harmonic content for small inverters
IEC 61000-3-12	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	☆☆☆	Maximum output harmonic content for medium size inverters

Reference	Title	Relevancy	Application
IEC 61000-2-2	Electromagnetic compatibility (EMC) - Part 2-2: Environment - Compatibility levels for low-frequency conducted disturbances and signalling in public low-voltage power supply systems	☆	Maximum level of voltage disturbances on a LV public grid
IEC 61000-3-3	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	☆☆	Non harmonic voltage disturbances on a LV grid and test systems. Valid for I ≤ 16 A per phase
IEC 61000-3-11	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	☆☆	Non harmonic voltage disturbances on a LV grid and test systems. Valid for 16 > I ≤ 75 A per phase
IEC 61000-6-1	Electromagnetic compatibility (EMC) - Part 6-1: Generic standards - Immunity for residential, commercial and light-industrial environments	☆	Immunity requirements and test for LV equipment installed in residential, commercial and light-industrial environments
IEC 61000-6-2	Electromagnetic compatibility (EMC) - Part 6-2: Generic standards - Immunity for industrial environments	☆☆	Immunity requirements and test for LV equipment installed in industrial environments
IEC 61000-6-3	Electromagnetic compatibility (EMC) - Part 6-3: Generic standards - Emission standard for residential, commercial and light-industrial environments	☆☆	Immunity requirements and test for LV equipment installed in residential, commercial and light-industrial environments
IEC 61000-6-4	Electromagnetic compatibility (EMC) - Part 6-4: Generic standards - Emission standard for -industrial environments	☆	Immunity requirements and test for LV equipment installed in industrial environments
IEC/TR 61000-3-14	Electromagnetic compatibility (EMC) - Part 3-14: Assessment of emission limits for harmonics, interharmonics, voltage fluctuations and unbalance for the connection of disturbing installations to LV power systems	☆☆	Guide to LV IEC 61000 series standards with examples of application
IEC/TR 61000-3-6	Electromagnetic compatibility (EMC) - Part 3-6: Limits - Assessment of emission limits for the connection of distorting installations to MV, HV and EHV power systems	☆	Harmonic current in MV and HV RRGU
IEC/TR 61000-3-7	Electromagnetic compatibility (EMC) - Part 3-7: Limits - Assessment of emission limits for the connection of fluctuating installations to MV, HV and EHV power systems	☆	Flicker effects and other rapid voltage changes in MV and HV RRGU
IEC/TR 61000-3-15	Electromagnetic compatibility (EMC) – Part 3-15: Limits – Assessment of low frequency electromagnetic immunity and emission requirements for dispersed generation systems in LV network	☆☆☆	Effects of unbalances in MV and HV RRGU

Reference	Title	Relevancy	Application
IEC/TR 61000-3-13	Electromagnetic compatibility (EMC) - Part 3-13: Limits - Assessment of emission limits for the connection of unbalanced installations to MV, HV and EHV power systems	☆	Effects of unbalances in MV and HV RRGU

A.4. Cables and connectors

Reference	Title	Relevancy	Application
EN 50618	Electric cables for photovoltaic systems	☆☆☆	Standard on cables for DC arrays
IEC 62852	Connectors for DC-application in photovoltaic systems - Safety requirements and tests	☆☆☆	IEC standard for PV connectors

A.5. Combiner boxes

Reference	Title	Relevancy	Application
IEC 61439-2	Low-voltage switchgear and controlgear assemblies - Part 2: Power switchgear and controlgear assemblies	☆☆☆	The main standard for the design and construction of LV switchgears and controlgear assemblies
IEC 62093	Balance-of-system components for photovoltaic systems – Design qualification natural environments	☆	Test sequence is to determine the performance characteristics of BOS components
IEC 62447-1	Safety requirements for power electronic converter systems and equipment Part 1: General	☆☆	Equipment for power conversion and electronic power switching
EN 50178	Electronic equipment for use in power installations	☆☆☆	Electronic equipment in power installations with respect to safety and reliability

A.6. LV switchgears and controlgear

Reference	Title	Relevancy	Application
IEC/TR 61439-0	Low-voltage switchgear and controlgear assemblies - Part 0: Guidance to specifying assemblies	☆	A guide with the explanation of main characteristics
IEC 61439-1	Low-voltage switchgear and controlgear assemblies - Part 1: General rules	☆☆☆	The main standard for the design and construction of LV switchgears and controlgear assemblies
IEC 61439-2	Low-voltage switchgear and controlgear assemblies - Part 2: Power switchgear and controlgear assemblies	☆☆☆	
IEC 61439-3	Low-voltage switchgear and controlgear assemblies - Part 3: Distribution boards intended to be operated by	☆☆	LV switchgears and controlgear for specific

Reference	Title	Relevancy	Application
	ordinary persons (DBO)		applications
IEC 61439-5	Low-voltage switchgear and controlgear assemblies - Part 5: Assemblies for power distribution in public networks	☆☆	
IEC 61439-6	Low-voltage switchgear and controlgear assemblies - Part 6: Busbar trunking systems (busways)	☆☆	
IEC 61439-7	Low-voltage switchgear and controlgear assemblies - Part 7: Assemblies for specific applications such as marinas, camping sites, market squares, electric vehicles charging stations	☆☆	
IEC 60947-3	Low-voltage switchgear and controlgear - Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units	☆☆☆	Characteristics of LV circuit-breakers and protection devices
IEC 62626-1	Low-voltage switchgear and controlgear enclosed equipment - Part 1: Enclosed switch-disconnectors outside the scope of IEC 60947-3 to provide isolation during repair and maintenance work	☆☆☆	Characteristics of LV circuit-breakers and protection devices

A.7. HV switchgears and controlgear

Reference	Title	Relevancy	Application
IEC 62271-1	High-voltage switchgear and controlgear - Part 1: Common specifications	☆☆	All the PV plants connected to the MV grid
IEC 62271-100	High-voltage switchgear and controlgear - Part 100: Alternating current circuit-breakers	☆☆	
IEC 62271-103	High-voltage switchgear and controlgear - Part 103: Switches for rated voltages above 1 kV up to and including 52 kV	☆☆	
IEC 62271-200	High-voltage switchgear and controlgear - Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV	☆☆	
IEC 62271-202	High-voltage switchgear and controlgear - Part 202: High-voltage/low-voltage prefabricated substation	☆☆	

A.8. Transformers

Reference	Title	Relevancy	Application
IEC 60076-8	Power transformers - Part 8: Application guide	☆☆	MV/LV dry-type and liquid-filled transformers
IEC 60076-11	Power transformers - Part 11: Dry-type transformers	☆☆	
IEC 60076-13	Power transformers - Part 13: Self-protected liquid-filled transformers	☆☆	
EN 50588-1	Medium power transformers 50 Hz, with highest	☆☆☆	

Reference	Title	Relevancy	Application
	voltage for equipment not exceeding 36 kV. Part 1: General requirements		
IEC 61558-1	Safety of power transformers, power supplies, reactors and similar products - Part 1: General requirements and tests	☆☆	LV transformers

A.9. Electrical installation

Reference	Title	Relevancy	Application
IEC 60364-1	Low-voltage electrical installations - Part 1: Fundamental principles, assessment of general characteristics, definitions	☆☆	Main standards for electric safety
IEC 60364-4-41	Low-voltage electrical installations - Part 4-41: Protection for safety - Protection against electric shock	☆☆	
IEC 60364-4-42	Low-voltage electrical installations - Part 4-42: Protection for safety - Protection against thermal effects	☆☆	
IEC 60364-4-43	Low-voltage electrical installations - Part 4-43: Protection for safety - Protection against overcurrent	☆☆	
IEC 60364-4-44	Low-voltage electrical installations - Part 4-44: Protection for safety - Protection against voltage disturbances and electromagnetic disturbances	☆☆	
IEC 60364-5-52	Low-voltage electrical installations - Part 5-52: Selection and erection of electrical equipment - Wiring systems	☆☆	
IEC 60364-5-53	Electrical installations of buildings - Part 5-53: Selection and erection of electrical equipment - Isolation, switching and control	☆☆	
IEC 60364-5-54	Low-voltage electrical installations - Part 5-54: Selection and erection of electrical equipment - Earthing arrangements and protective conductors	☆☆	
IEC 60364-6	Low-voltage electrical installations - Part 6: Verification	☆☆	
IEC 60364-7-712	Electrical installations of buildings - Part 7-712: Requirements for special installations or locations - Solar photovoltaic (PV) power supply systems	☆☆	Standard for electric safety of PV plants
IEC 62548	Photovoltaic (PV) arrays - Design requirements	☆☆☆	Fundamental for the design of DC sections of PV plants
IEC 62446-1	Photovoltaic (PV) systems - Requirements for testing, documentation and maintenance - Part 1: Grid connected systems - Documentation, commissioning tests and inspection	☆☆☆	Important for the start-up and verification of PV plants
IEC 61724-1	Photovoltaic system performance - Part 1: Monitoring	☆☆	Monitoring of PV system,

Reference	Title	Relevancy	Application
IEC 61724-2	Photovoltaic system performance - Part 2: Capacity evaluation method	☆☆	power capacity and energy evaluation
IEC 61724-3	Photovoltaic system performance - Part 3: Energy evaluation method	☆☆	
IEC 61829	Crystalline silicon photovoltaic (PV) array - On-site measurement of I-V characteristics	☆☆	Measurement of PV arrays on field
IEC 62305-1	Protection against lightning - Part 1: General principles	☆☆	Main standards on lightning effects
IEC 62305-2	Protection against lightning - Part 2: Risk management	☆☆	
IEC 62305-3	Protection against lightning - Part 3: Physical damage to structures and life hazard	☆☆	
IEC 62305-4	Protection against lightning - Part 4: Electrical and electronic systems within structures	☆☆	

A.10. PV mounting system

Reference	Title	Relevancy	Application
EN 50583-1	Photovoltaics in buildings. Part 1: BIPV modules	☆☆	Building Integrated PV
EN 50583-2	Photovoltaics in buildings. Part 2: BIPV systems	☆☆	Building Integrated PV
UL 2703	Outline of Investigation for Mounting Systems, Mounting Devices, Clamping/Retention Devices, and Ground Lugs for Use with Flat-Plate Photovoltaic Modules and Panels	☆☆	Important document especially for Building Integrated PV

A.11. Grid connection

Reference	Title	Relevancy	Application
EN 50160	Voltage characteristics of electricity supplied by public electricity networks	☆☆	Specifications of PQ levels in public networks
EN 50438	Requirements for the connection of micro-generators in parallel with public low-voltage distribution networks	☆	Different requirements for connection in Europe
CLC/TS 50549-1	Requirements for generating plants to be connected in parallel with distribution networks – Part 1: Connection to a LV distribution network above 16 A	☆☆	Technical specifications for the LV grid connection
CLC/TS 50549-2	Requirements for generating plants to be connected in parallel with distribution networks – Part 2: Connection to a MV distribution network	☆☆	Technical specifications for the LV grid connection
IEC TS 62786	Distributed energy resources connection to the grid	☆☆	Technical specifications for grid connection

Reference	Title	Relevancy	Application
IEC TS 62749	Assessment of the power quality – characteristics of the electricity supplied by public networks	☆☆	Specifications of PQ levels in public networks
EN 61727	Photovoltaic (PV) systems - Characteristics of the utility interface	☆	General requirements for grid connection