Solar Energy Plants Grid Connection Code

In addition to the
Egyptian Transmission Grid
Code and The Egyptian Distribution Network

Code March 2017

Contents

1 PURPOSE

The objective of the Solar Energy Grid Connection Code is to determine the requirements for new or modified Solar Energy Plants, so that it ensures security and quality parameters of the grid.

Notwithstanding the provisions of the Egyptian Transmission Grid Code (the Grid Code), and the Egyptian Distribution Network Code (the Distribution Code), this Solar Energy Grid Connection Code specifies the special requirements for the connection of Solar Energy Plants to the Medium, High, Extra High Voltage distribution and transmission systems (the Grid). This Solar Energy Grid Connection and the Egyptian Transmission Grid Code /the Egyptian Distribution Network Code (the Distribution Code) are two complementary documents.

2 SCOPE

This Solar Energy Grid Connection Code shall apply to all Solar Plants (Photovoltaic (PV) plants and Thermal Solar Plants) to be connected to the Grid from the date this Code is enforced.

This Code applies to:

a) Medium Size Solar Plants (MSSP) with nominal generation capacity of 500kW to <20MW
b) Large Size Solar Plants (LSSP) with nominal generation capacity of ≥20MW (inclusive and upward).

For the photovoltaic plants with generation capacity of less than 500 KW, refer to small scale PV (ssPV) Code[1].

3 DEFINITIONS

Actual Active Power	The amount of active power that the Solar Plant could produce based on current solar irradiance and ambient temperature conditions.
Connection Agreement	An agreement between the Solar Power Producer and the Grid Operator setting out the terms relating to the connection of the Solar Plant to the Grid.
Extra High Voltage	Voltage levels above 132 kV.
Distribution Code	The Egyptian Distribution Network Code
Grid	The High Voltage and Extra High Voltage transmission and medium voltage distribution systems of interconnected network, substations, and related facilities.

Grid Code	The Egyptian Transmission Grid Code (ETGC)
Grid Connection Point/Point of Common Coupling	The point at which Solar Plant is connected to the Grid. (at the high voltage terminals of generator transformer). This corresponds to the point of property exchange from the Solar Plant to the Grid.
Grid Operator	The entity responsible for grid operations. These functions will be carried out by the Egyptian Electricity Transmission Company (EETC) and or the relevant Distribution Company when applicable.
High Voltage	Voltage levels from 33 kV up to 132 kV.
LSSP	Large-size Solar Plant with nominal generation capacity of ≥20MW (inclusive and upward).
MSSP	Medium-size Solar Plant with nominal generation capacity of 500kW to <20MW
Medium Voltage	Voltage levels from 11 kV up to 22 kV.
National Control Center	National Energy Control Center at EETC in Cairo
Rated Power of a Solar Plant	The maximum active output power of the Solar Plant at the Grid Connection Point under normal state conditions.
Rated Power of a Solar Inverter Generator	The maximum active output power, which a solar inverter is constructed to produce continuously under normal state conditions.
Regional Control Center	Energy Control Centers distributed in the regions belongs to Grid Operator
Solar Plant	A collection of elements and devices that produces energy by means of Solar Energy conversion into electrical energy.
Solar Plant Operator	Person, Company or Consortium who is going to operate the Solar Plant.
Solar Power Producer	Person, Developer, Company or Consortium willing to install and connect to the Grid (or upgrade an existing connection).
Start-up	Solar Plant production start right after commissioning or after a full decoupling.

Table 1: Definitions

4 GRID CONNECTION REQUIREMENTS

4.1 Grid Connection Point

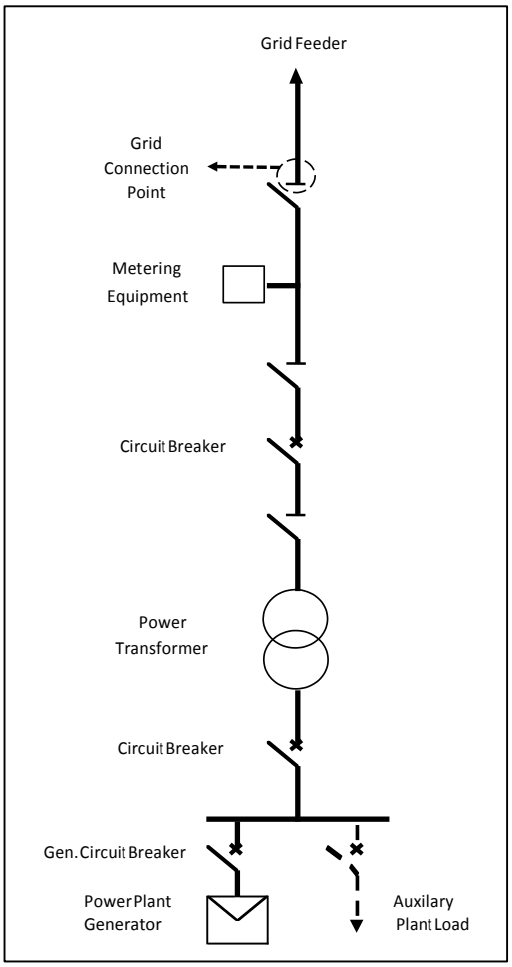

Figure 1: Grid Connection Point

The connection point shall be the point at which Solar Plant is connected to the Grid. The Point shall have the following characteristics:

a) It shall be at Grid Operator incoming feeder switch on the highest voltage side at the substation in the Solar Plant connecting to the Grid.
b) The Solar Plant shall be connected to the grid such as:
    i. MSSP connects to Medium or High Voltage Networks; and,
    ii. LSSP connects to High or Extra High Voltage Networks
c) When the Solar Plant comprises different substations, the Grid Connection Point shall be in the last substation gathering the energy production of the entire Solar Plant.
d) Elements and devices at the Grid Connection Point must comply with the requirements in chapter-4.2 within this code.
e) The Grid Connection Point shall be Gross Metering of the total energy supplied by the Solar Plant less the consumption for the Auxiliary Plant Load according to the Metering

equipment that must comply with provisions in Metering Code within Grid Code.

This Grid Connection Point also corresponds to the point of property exchange from the Solar Plant to the Grid.

4.2 Solar Plant Components

4.2.1 Solar Inverters

The inverter shall meet the grid connection ranges and the operational requirements specified in this code. The inverters shall meet the requirements in IEC 62109-2, also be certified according to IEC 62116. In the case of LSSP, the inverter shall also be able to control the reactive power or cos φ with an accuracy of +/- 2%.

The Solar Plant shall integrate a synchronization unit (e.g. a phase-locked loop (PLL) or similar) to keep inverters synchronized with the grid before and after being connected to the grid so that 1) an inverter can be connected to the grid and 2) the inverter can feed the right amount of power to the grid even when the grid voltage changes its frequency, phase, and amplitude.

4.2.2 AC Switchgear

The switchgears shall be certified according to IEC 62271. The switchgear shall be rated for operational voltage and current, and short circuits power according to that in the Grid Code. The switchgear shall have as minimum two independent tripping coils and be secured by locks in off/earth positions, with labels clearly showing the switch position. In the particular case of LSSP, it must be remotely controllable.

4.2.3 Power Transformer(s)

The transformer(s) shall be certified according to IEC 60076 for the power transformer, IEC 60085 for electrical insulation and IEC 60214 for tap changers, and have an efficiency of 96% or higher.

4.2.4 Plant Communications

The Solar Plant monitoring system and the security system will require a communications medium with remote access for visibility and control of the plant. The telecommunication equipment, the remote monitoring and controlling equipment and the communication link shall meet the requirements in the Grid Code and the Distribution Code. Among others, the following communication means are therefore required (when applicable):

a) For LSSP:
   i. Dedicated voice channel(s) for communication between Solar Plant operator and National Control Center.
   ii. Main and Redundant real-time and bidirectional communication between the National Control Center and the Solar Plant.
   iii. Technologies used for communication shall be Fiber Optic or HV PLC (Annex I in chapter 10 in this Code provides detailed required technical characteristics).
   iv. Automatic data acquisition and monitoring system for remote measurements and eventual operation as indicated in this code.
   v. Communication shall exchange information from and to the metering devices and control switchgears.
   vi. The gateways between LSSP and the National Control Center shall use the IEC-60870-5-101/104 implementation protocol.

b) For MSSP
   i. Dedicated voice channel(s) for communication between Solar Plant operator and Dispatch Center.
   ii. Main communication channel between the Dispatch Center and the Solar Plant metering device shall be established.
   iii. Technologies for communication available shall be Fiber Optic or Mobile Communications (GPRS or similar).
   iv. The metering data protocol shall be based on international standards, such as DLMS/COSEM, IEC 61850 or others (to be agreed at design stage).

4.2.5 Real Time Data Measuring, Monitoring and Control

The Solar Plant must have technical equipment at the Grid Connection Point to process and or transfer the following information for the power system management systems furnished with a real-timestamp. The real-time measurement, monitoring and control data shall be stored locally (up to 2 year of historical data for LSSP and up to 2 year of historical data for MSSP), and made available when required. The following parameters shall be measured and or control:

a) Measured values from the Solar Plant:
   i. Active Power(total KW) and Active Energy (total kWh)
   ii. Reactive Power (total kVAr) and Reactive Energy (total kVArh)
   iii. Voltage (phase voltage & line voltage)
   iv. Current
   v. Frequency (f)
   vi. For LSSP: Solar Irradiance (inclined and horizontal plane). The probe shall measure the ambient temperature inside the area of the solar panels according to the requirements in IEC 61853-1(for MSSP when applicable).
   viii. Total harmonics % in Voltage and Current at the Grid Connection Point.

b) Status signals from the Solar Plant:
   i. Grid Connecting Transformer tap position (if tap changer is existing at the substation's transformer).
   ii. Status from switching equipment (open, closed, or trip): circuit breakers, disconnectors and earthing switches if required for operation or system evaluation.
   iii. Telecommunication system alarms
   iv. Protection signals at the grid side
   v Inverter Status (applicable for MSSP)

c) Set-point values, given from the Grid Operator to the Solar Plant:
   i. Active power set-point
   ii. Reactive power set-point or power factor set-point
   iii. Status: Solar Plant is not allowed to start
   iv. Status: Solar Plant must disconnect

For the purpose above, the following technology solutions shall be implemented:

4.2.5.1 Regarding LSSP

At the LSSP substation, the internal Bay Bus (or LAN) shall have an autonomous behavior (i.e. local control), inter locking, sequence of events, etc. The substation local network shall have intelligent interface to communicate with other equipment to collect data from and/or send control actions to the IEDs, switchgear devices, measurement devices and protection relays, to meet the requirements for measurement values, status signals and set-point values indicated in above.

A **digital fault recorder** shall be installed at the Solar Plant for monitoring of the grid connection point values, with following characteristics:

a) Configurable sampling frequency up to 12 kHz.
b) Configurable triggers, including but not limited to over/under voltage level, over/under current level, unbalance of phases, dU/dt, and frequency variation.
c) Virtual channels for real-time calculations, including but not limited to active power and reactive power, unbalance factor.
d) TCP/IP communication port.

4.2.5.2 Regarding MSSP

For MSSP, smart meters, instead of substation monitoring and control system, shall at least establish the remote communication to the dispatch center (if applicable). In this case, the smart meters shall be able to establish real-time communication with the Regional Control Center. The measurement values indicated above shall be transmitted on demand, or periodically with configurable intervals.

4.2.6 Solar Plant Implementation Requirements

The design, manufacturing and installation of components used in the solar plant (e.g. solar modules, arrays, towers and others) shall be certified according to the relevant international standards.

The solar plant site implementation shall be compliant with IEC 60364 series of standards. The cabling and accessories used in the site shall comply with IEC 60227 series for LV (below 1KV) and IEC 60502 series for HV installations.

Additionally, all relevant components shall be certified according to the IEC 60068-2 series for Basic Environmental tests, at least for IEC 60068-2 /1 cold, /2 dry, /14 change of temperature, and /30 Damp heat.

The Solar Plant Grounding System shall be compliant with the provisions in the Clause 4.2.8 of the Section 4 Protection Code in the Grid Code and/or relevant Clause in the Distribution Code.

The Grid Operator may ask for the Availability of Facility verification documents of the installed equipment in the solar plant, for recording purposes. Additionally, the Grid Operator may periodically request for monitoring purposes the facility availability information during the operation.

4.3 Grid Connection Ranges (Operational Ranges)

4.3.1 Voltage ranges

In case of a deviation of the voltage at the Grid Connection Point from its permissible voltage range, the Solar Plant shall be able to deliver Actual Active Power when the voltage at the Grid Connection Point remains within the ranges specified by **Table 2**.

Voltage range	Time period for Operation
0.85 pu – 1.10 pu	Unlimited
1.10 pu – 1.15 pu	30 minutes

Table 2: Minimum Operation Time Periods

Solar Plant shall be also capable of automatic disconnection from the Grid at specified voltages, if required by the Grid Operator.

4.3.2 Frequency ranges

In case of a deviation of the grid frequency from its permissible value, the Solar Plant shall perform as follows:

a) In case of frequency below 50Hz, the Solar Plant shall continue injecting active energy until the frequency is below 47.5Hz.
b) In case of over frequency between 50 to 50.2Hz the solar plant shall maintain the 100% of active power.
c) In case of frequency above 50.2Hz, the Solar Plant shall inject active energy up to 51.5Hz according to the provisions in chapter 5.1.2 in this Code

4.4 Start-up of the Solar Plant

The Solar Plant shall only be connected to the Grid if the frequency and the voltage at the Grid Connection Point are within the following limits, or as otherwise agreed to in the Connection Agreement:

Frequency:	48 Hz ≤ f ≤ 51 Hz
Voltage:	0.90 per unit ≤ U ≤ 1.10 per unit

Table 3: Solar Plant Start-up Ranges

During the start-up of the Solar Plant or of the solar inverter generators of the Solar Plant the increase of the active power shall not exceed 10 % of the Rated Power of the Solar Plant per minute.

4.5 Power Quality

All the Solar Plants connected to the Grid shall endeavor to maintain the voltage wave-form quality at the Grid Connection Point. The Solar Plants shall comply with the requirements of Section 5.3 (Power Quality Standards) of the Performance Code in theand/or the relevant clause in the (Distribution Code).

4.5.1 Harmonics

The maximum levels of harmonic distortion at the Grid Connection Point which are attributable to the Solar Plant shall follow the provisions in IEEE 519-1992 standard as set out in chapter 5.3.7 in Performance Code in the Grid Code and/or /or the relevant clause in the Distribution Code.

4.5.2 Flicker

The flicker, caused by the Solar Plant at the Grid Connection Point, must be within the following limits as per IEC61000-3-7 [3]:

Short term (10 minutes):	$P_{st} \leq 0.35$
Long term (2 hours):	$P_{lt} \leq 0.25$

Table 4: Flicker Requirements

Where:

P_{st} Short term flicker

factor over time periods of 10 minutes

P_{lt} Long term flicker factor over time periods of 2 hours

4.5.3 Voltage unbalance

Voltage unbalance is defined as the deviation between the highest and lowest line voltage divided by the average line voltage of three phases. Solar Plants shall be able to withstand voltage unbalance not exceeding 2% for at least 30 seconds as per the provisions in the chapter 5.3.5 of the Section 5 (Performance Code) in the Grid Code and/or /or the relevant clause in the Distribution Code .

4.5.4 Voltage fluctuations

Voltage fluctuations at the Grid Connection Point of a Solar Plant can occur because of switching operations within the Solar Plant facilities (i.e. capacitor banks, collection circuit transformers) due to inrush currents.

Voltage Fluctuation at Grid Connection Point shall be up to 3% of nominal voltage the Grid Code provided that this not constitutes a risk to the Grid or other User in the Grid Operator's view.

4.6 Grid Protection

The grid protections for the Grid Connection Point of the Solar Plant to the Grid shall be commissioned and the settings established, according to the Protection Code of the Grid Code. Solar Plant Developer/Applicant shall be responsible for the security of the elements of the Solar Plant.

Function	Setting range	Recommended settings	
		Level	Setting time
Overvoltage U>>	1.00 – 1.30 Un	1.15 x Un	≤ 3 s
Undervoltage U<<	0.15 – 1.00 Un	0.30 x Un	1 s
Undervoltage U<	0.15 – 1.00 Un	0.80 x Un	3 s
Overfrequency	50 – 52 Hz	51.5 Hz	≤ 100 ms
Underfrequency	47.5 – 50 Hz	47.5 Hz	≤ 500 ms

Table 5: Setting of the grid protection at the solar inverter generators (U_n: rated voltage)

The selection of equipment and protections, regarding the survivability and conditions of the Plant during or after any incident, shall be done in accordance with the conditions and response time established by the Grid Operator. The settings of the grid protection device in the Solar Plant must conform to Table 5 unless agreed otherwise in written with the Grid Operator.

5 OPERATIONAL AND MAINTENANCE REQUIREMENTS

5.1 Active power control

5.1.1 Active power Output

The Solar Plant shall continue injecting Actual Active Power within the frequency range of 47.5Hz up to 50.2 Hz or grid voltage range at the Grid Connection Point for the time periods given in Figure 2.

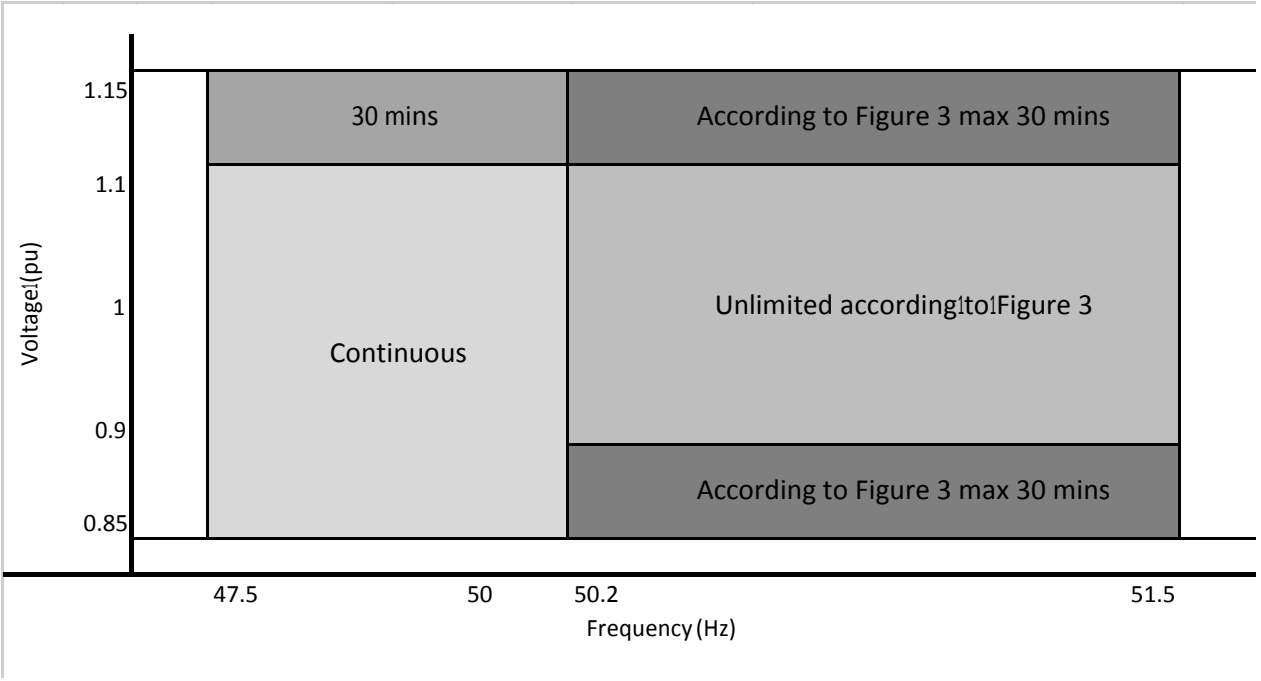

Figure 2: Requirements on the output power of the Solar Plant in case of grid frequency and grid voltage variations (quasi-stationary observation)

5.1.2 Active power reduction due to over frequency

For grid frequencies in the range from 50.2 Hz to 51.5 Hz the Solar Plant has to reduce active output power according to Equation 1 and Figure 3.

The output power must be reduced by:

$$\Delta P = 0.4 * PM * (\Delta f/Hz) \qquad \text{Equation 1}$$

PM: actual output power before the grid frequency exceeds 50.2 Hz
Δf: actual grid frequency minus 50.2 Hz

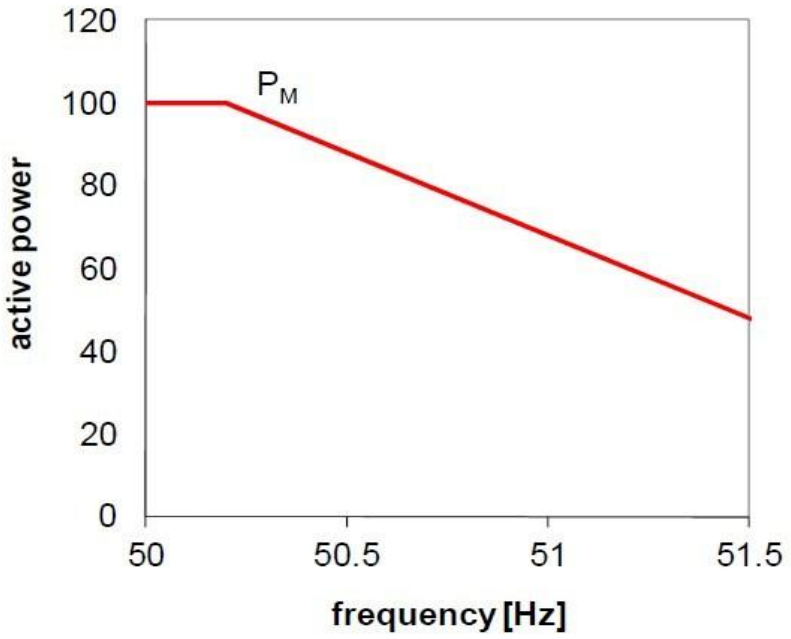

Figure 3: Active power reduction due to over frequency

The reduction or increase ramp will be given as percentage of the maximum power, in steps of a 10% each.

5.1.3 Curtailment

The curtailment consists in the capacity of the Grid Operator to limit the output of the Solar Plant in power (MW) exclusively for security reasons. The order will be sent to the Solar Plant through the communications means described below in this chapter as set point for the plant representing its maximum power generation. The reduction order will be given as percentage of the maximum power, in steps of a 10% each. The Solar Plant Operator is responsible to execute such order within one minute of reception.

On request of the Grid Operator, Solar Plant Operator must reduce the active output power, amongst others, in the following cases:

a) Potentially risk for a safety grid operation
b) Bottlenecks and risk of overloading in the Grid
c) Risk of islanding
d) Loss of the dynamic or steady state grid stability
e) Maintenance.

In case of an active output power reduction, the Solar Plant must follow the set-point signal of the Grid Operator within one minute. The Solar Plant must be able to reduce the Actual Active Power within steps of 10 % of the nominal generation capacity of the Solar Plant. Only for output power below 10% of nominal generation capacity the Solar Plant can be disconnected from the Grid.

The Grid Operator will reset this order and allow the maximum possible generation, as soon as the security constrains disappears.

In all cases communications must be registered and or recorded for monitoring purposes.

5.1.3.1 LSSP Case

The LSSP Solar Plant must be able to adapt the maximum energy injection as per the set-points submitted by the Grid Operator through one of the following means:

a) SCADA; or,
b) Dedicated Control and monitoring system; or,
c) Verbal communication to the operator.

5.1.3.2 MSSP Case

The MSSP Solar Plant must be able to adapt the maximum energy injection as per the set-points submitted by the Grid Operator through one of the following means:

a) SCADA; or,
b) Verbal communication to the operator.

5.2 Reactive power control

The Solar Plant must be able to control reactive power at the Grid Connection Point in a range of 0.95 lagging to 0.95 leading at maximum active power and according to Figure 4 for MSSP and for LSSP.

The Solar Plant must be able to control reactive power as follows:

a) Set-point control of reactive power Q
b) Set-point control of power factor (cos φ)
c) Fixed power factor (cos φ)
d) Characteristic: power factor as a function of active power output of the Solar Plant, cos φ (P)
e) Characteristic: reactive power as a function of voltage, Q(U)

The Solar Plant must have an input signal for a set-point value at the Grid Connection Point, to control reactive power or cos φ of the Solar Plant. The Solar Plant shall be able to received set-point with an accuracy of 1kVar. The Grid Operator will provide the set-point signal through verbal communication or SCADA, whichever is present. The Solar Plant must follow the set-point signal of the Grid Operator within one minute.

When operating at an active power output below the Rated Capacity of the Solar Plant (P<Pmax), the Solar Plant shall be able to be operated in every possible operating point in the P-Q Diagram for each solar plant size, see Figure 4.

For LSSP, even at zero active power output (e.g. during the night), reactive power injection at the Grid Connection Point shall fully correspond to the P-Q Diagram taking the auxiliary service power, the losses of the transformers and the Solar Plant cabling into account.

The maximum Q capacitive and the maximum Q inductive in Figure 4 are calculated from the nominal generation capacity of the Solar Plant and the power factor of 0.95.

The use of capacitor and/or reactor banks to meet this P-Q requirement at the Grid Connection Point is acceptable.

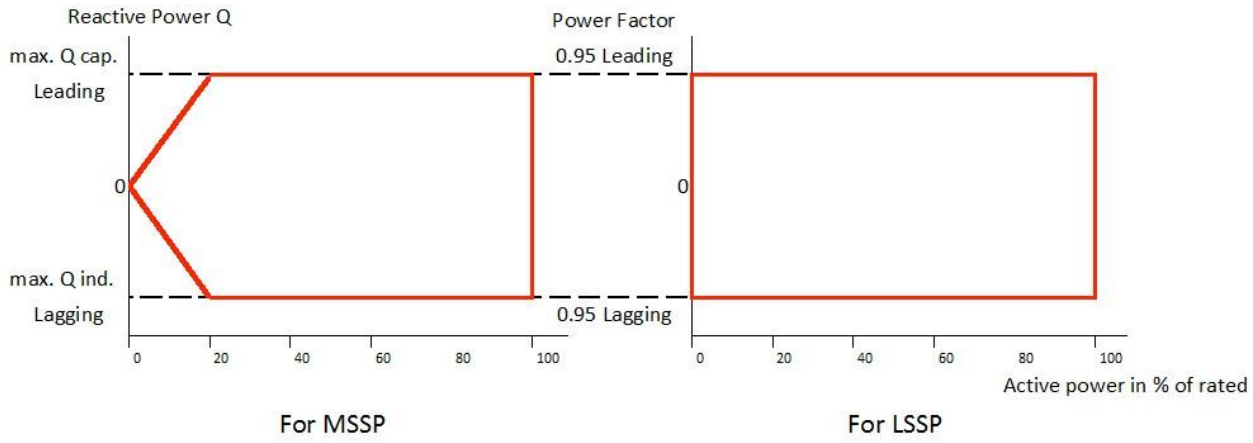

Figure 4: P-Q Diagram for MSSP (left) and for LSSP (right)

Additional requests for reactive compensation shall be discussed and agreed in the *Connection Agreement* as per section 6.3.

5.3 Fault Ride Through

For temporary voltage drops, when positive sequence voltage is above the curve in Figure 5, Solar Plants have to ride-through the grid fault without disconnection from the Grid.

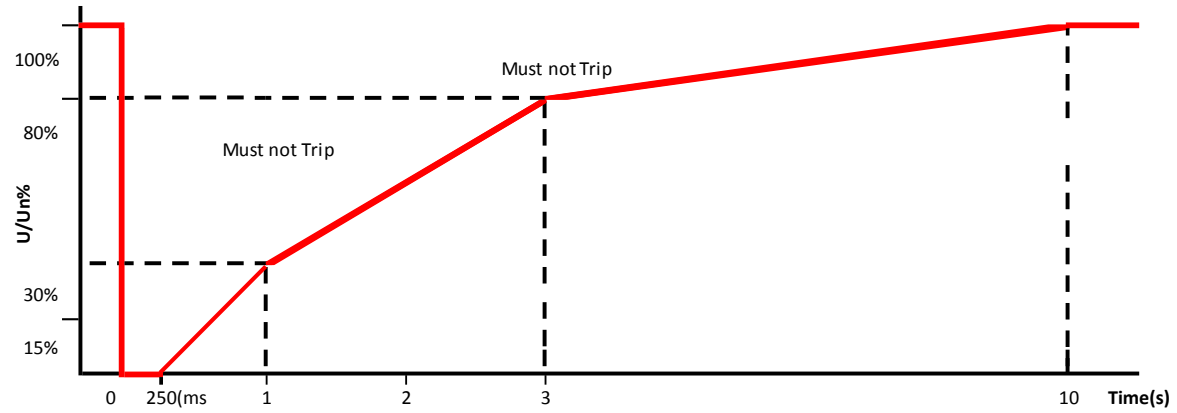

Figure 5: Fault ride through profile for a Solar Plant

The Solar Plant shall trip if all phase-to-phase voltages are below the curve in Figure 5.

During the temporary voltage drop Solar Plant must fulfill the following requirements concerning reactive power or reactive current:

a) For 3-phase faults the Solar Plant must inject reactive current according to Figure 6 and Equation 2 and Equation 3 for the time period 250ms after the beginning of the fault until fault clearance.

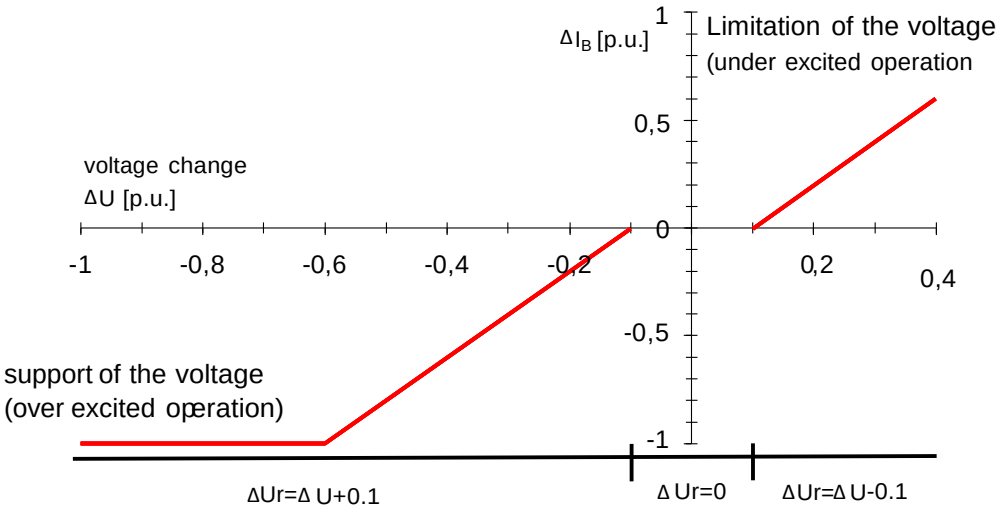

Figure 6: Current injection during the fault (k=2)

The above line represents the required minimum reactive current, expressed by the ratio of the reactive current and the nominal reactive current in per unit, against the voltage drop, expressed by the ratio of the actual voltage value and its nominal value in per unit at the grid connection point.

$$\frac{\Delta I_B}{I_N} = k \times \frac{\Delta U_r}{U_N}$$ Equation 2

$$\Delta U = U - U_0$$ Equation 3

Variables:

U_N: rated voltage
I_N: rated current
U: voltage during fault
ΔI_B: required reactive current change during fault
U_0: pre-fault voltage
ΔUr: relevant voltage change during the fault

The factor k shall be adjustable in the range from 0 to 4.

b) For unsymmetrical faults, it is not permissible that during the duration of the fault, reactive currents be fed into the Grid which will give rise to voltages higher that 110% nominal voltage in non-faulty phases at the Grid Connection Point.

After fault clearance the active power output of the Solar Plant must reach the same level as before the fault within a time period of 10s after fault clearance and the consumption of reactive power of the Solar Plant must be equal or below the consumption of reactive power before the fault.

5.4 Maintenance

The Solar Plant shall coordinate with the Grid Operator the Maintenance program for the Solar Plant. In this regard the Solar Plant Operator shall perform the following reports:

a) Annual Maintenance Program: the Solar Plant Operator shall propose the Annual Maintenance Program as per the provisions in chapter 7.6.2 in Section 7 (Operation Code) of the Grid Code and/or /or the relevant clause in the Distribution Code. Modifications of the Annual Maintenance Program shall be reported to the Grid Operator for approval before implementation.
b) Report on incidences: Each time that there is an incidence in the plant that affects the continuity of supply and or the Actual Active Power, the Solar Plant Operator shall:
    i. Verbally inform the Grid Operator. as soon as the incidence is made known to the Solar Plant Operator, about the reasons for the incidence and the expected recovery time.
    ii. Submit the Incidence report as per the Grid Operator template 3 days after the recovery.

5.5 Forecast

The Solar Plant Operator shall have the capability to produce and submit to the Grid Operator the day- ahead and week-ahead hourly Actual Active Power production forecast.

These forecasts shall be provided by 10:00 a.m. on a daily basis for the following 24 hours and 7 days for each 1-hour time-period, by means of an electronic interface in accordance with the reasonable requirements of Grid Operator's data system.

The Solar Plant Operator shall provide the Grid Operator with declarations whenever changes in the submitted nominal generation capacity occurs or are predicted to occur.

5.6 General Control Requirements

Solar Plant Operator has to be physically present at the Solar Plant's location during all operation times, with access to the plant's common control system.

The plant operator has to follow the Grid Operator's instructions and he has to decide which specific element(s) has (have) to be manipulated (load change, switch off) in order to achieve the desired (power) injected to the Grid Connection Point.

5.7 Health and Safety

The Solar Plant Operator shall follow the Health and Safety provisions issued by the Grid Operator for any maintenance operation affecting the Grid Connection Point and or upstream network.

6 GENERAL ADMINISTRATIVE CONNECTION PROCESS

In order to setup and connect a Solar Plant, at the first stage, the Applicant for solar plant promotion shall fulfill the following steps:

Figure 7: Solar Plant Connection General Requirements

6.1 Application for Connection Point

The applicant shall submit the "Application for Grid Connection Point" to the Grid Operator, according to the requirements in the Grid Code for EETC or any other requirements for the distribution companies regarding the MSSP.

The connection application shall, among others, include the description for the purpose of connection, the desired connection point's location and voltage level, the relevant standards as in Planning Code, and desired date of connection.

The process of applications will be first come, first served, and grid operator is responsible to process and respond to the application. The grid operator will decide on connection point application acceptance based on capacity studies and investment policies.

The Grid Operator will submit a written response for Application for Grid Connection Point within 30 business days after its reception from the applicant, with either accepting or rejecting the applied connection point. If the Application for Grid Connection Point is rejected, the Grid Operator shall propose at least two connection alternatives, namely: a) one at the same voltage level; and, b) one at the nearest technically suitable network regardless of the voltage level.

6.2 Solar Plant Development Application

Within 30 business days after reception of the written response for Application for Grid Connection Point the applicant shall submit its Solar Plant Development Application to Grid Operator, , and any other entity defined by Grid Operator (when applicable). The application shall include the following:

a) Confirmation and acceptance of the Connection Point proposed and or accepted by the Grid Operator.
b) Supporting Information for solar plant development:
    i. Layout Design of the Solar Plant as specified in the Grid Code, including: electrical layout, expected cabling and specific location of solar generators.
    ii. Design Technical data of the Solar Plant.
    iii. Design Technical data of the solar inverter generators and panels.
    iv. Design Technical data of the transformers
    v. Reactive compensation details
    vi. Layout and design of the grid connection and technical data of the switchgear.
    vii. Protection concept
    viii. Implementation Time schedule

Within 30 business days from the reception of the application the Grid Operator shall review the drawings and documents of the Solar Plant before the construction of the Solar Plant and

check if it complies with this Solar Plant Code[1]. If documents comply with existing regulations, the Grid Operator shall invite the Solar Plant Producer to finalize and sign the Connection Agreement.

6.3 Connection Agreement

Grid Operator will sign a "*Connection Agreement*" that shall be binding on both parties. It shall define, among others, the deadline for the approval of Clearance for Connection (as per chapter-6.5), which in no case (unless any regulatory changes) shall be longer than **one calendar year** for MSSP and **two Calendar years** for LSSP from the date of the Connection Agreement.

If the aforementioned deadline is not met the Grid Operator may suspend the connection agreement and thus release the connection point.

6.4 Initial Tests

The Solar Plant Producer is responsible to ensure all initial tests are performed successfully, and shall deliver to Grid Operator a report with the detailed initial test results, prior to connection to the grid. The Solar Plant Producer shall perform and conduct the Initial Tests as per the provisions in in chapter-7.1 in this Code.

The initial test results report (must be verified by a reputable independent engineering company for LSSP), and, among others, shall include the following:

a) Site Installation Report according to the IEC 60364-6.
b) The performance verification reports according to IEC 62446 and IEC 61724 for PV plants and according to EN 12975 or UNE 206010 or NREL/SR-5500 for CSP plants.
c) Certification of compliance for the key grid connection components, as required in this Code
d) Certification of compliance for monitoring and control system, as well as the communication protocols and technologies, as required in this Code.
e) Certification of other additional requirements as per the Connection Agreement.
f) Certification of compliance with cabling standards as per IEC 60227 series for LV (below 1KV) and IEC 60502 series for HV installations.
g) Certification for compliance of the Basic Environmental Test of the components, according to the IEC 60068-2, at least for: IEC 60068-2/1-Cold, /2-Dry Heat, /14-Change of Temperature and /30-Damp heat.

Results of Initial Tests shall be included in the Clearance for Connection (as per chapter-6.5).

[1] The solar plant applicant is responsible to comply with all requirements of this Solar Grid Code. The verification of the Grid Operator at this stage is not an approval of the solar plant development plan.

6.5 Clearance for Connection

Once the plant is ready for connection to the Grid and after successful compliance with the Initial Tests, The Solar Plant Producer shall submit to the Grid Operator a request for Clearance for Connection including:

a) As-built layout of the Solar Plant as specified in the Grid Code and/or the relevant clause in the Distribution Code (if applicable), including: electrical layout, labeling, cabling, specific location of solar inverter generators, and construction plans.
b) Technical data of the Solar Plant and compliance certificates.
c) Technical data of the solar inverter generators and compliance certificates (when applicable).
d) Technical data of the transformers and compliance certificates (when applicable)
e) Layout and technical data of the switchgear and compliance certificates.
f) Layout of the grid connection (switchgear)
g) A detailed calculation of the fault in feed has to be provided to specify 3-phase short circuit in feed from the system and how the value has been determined.
h) As-built Protection scheme
i) Initial Tests Report
j) In the case of LSSP, the Solar Plant Producer shall also submit a Solar Plant Dynamic Model in PSS/E with an official third party report that validates and certifies the required mathematical model and plant performance.

Within 30 business days, the Grid Operator shall review the final Solar Plant construction documents, the correspondent Initial Tests. Grid Operator may request a visit to the Solar Plant to check *in situ* the documents provided. In case compliance with this Solar Code, the Connection Agreement and of successful initial testing, the Grid Operator shall issue a correspondent "*Clearance for Connection*".

6.6 Commissioning Test and Certificate

The Solar Plant Producer shall perform the Commissioning Tests in presence of the Grid Operator as per provisions in chapter-7.2 in this Code. The Grid Operator shall certify that the Solar Plant complies with the provisions in this Code and issue a "*Commissioning Certificate*" comprising the main parameters of the Solar Plant.

In case during operation the Solar Plant does not fulfill the requirements given in this Solar Energy Plant Grid Connection Code, the Grid Operator is authorized to disconnect the Solar Plant from the Grid. In such cases the reconnection of the Solar Plant must be agreed with the Grid Operator after the later verifies the fulfillment of the requirements that provoked the disconnection.

7 TESTING AND COMMISSIONING

The Solar Plant operator shall keep written records of test results and protection settings. The Solar Plant operator shall regularly maintain the protection systems in accordance with Grid Code/ Distribution Code requirements.

In addition, it may be necessary to perform tests on ad-hoc basis for purposes such as ascertaining level of harmonic emissions, voltage rise, protection operation in the context of system changes, fault investigation and protection changes etc.

7.1 Initial Tests

7.1.1 Applicable Standards

Prior to the connection to the grid, the Developer/ Applicant is responsible to ensure that all solar plant components (separately and in combination) are compliance with this grid code, as per relevant international standards in Annex-II. The installation and performance of the power plant key components and functions shall be tested and verified, as required in the connection agreement.

The initial testing results shall be presented with verification of reputable independent engineering companies, demonstrating the compliance of the solar plant with internationally recognized standards as following:

7.1.1.1 For PV:

a) IEC 62446: Grid connected photovoltaic systems - Minimum requirements for system documentation, commissioning tests and inspection.
b) IEC 61724: Photovoltaic system performance monitoring – Guidelines for measurement, data exchange and analysis
c) IEC 62305-3: Protection against lightning, part 3 physical damage and life hazards in structures.

7.1.1.2 For CSP:

a) EN 12975: Thermal solar systems and components – Solar collectors - Part 2: Test methods
b) NREL/SR-5500-48895: Utility-Scale Parabolic Trough Solar Systems: Performance Acceptance Test Guidelines
c) NREL/SR-5500-57272: Utility-Scale Power Tower Solar Systems: Performance Acceptance Test Guidelines.
d) UNE 206010: Tests for verifying the performance of solar thermal power plants with cylindrical parabolic trough collector technology.
e) ASTM E905: Standard Test Method for Determining Thermal Performance of Tracking Concentrating Solar Collectors.

- Latest version of applicable standard for any other technology used (Dish, Compact linear Fresnel reflector,…) to be applied.
- All the other tests for such turbines are already covered in the Grid Code

7.1.2 List of Minimum Initial Tests

The initial tests shall include but not limited to the followings:

a) Inverter testing according to IEC 61683, IEC 62109-1/2, IEC 62116
b) Switch gear and circuit breaker testing according to IEC 62271
c) Earthing arrangements according to IEC 60364-5-54
d) Open-Circuit Voltage (Voc) Test;
e) Short Circuit current (Isc) Test;
f) Communication testing (as per selected communication for within the solar plant and via simulation to remote interfaces).
g) In the case of LSSP: monitoring and control system functional testing and for MSSP (when applicable).
h) Performance verifications, according to best practice standards and guidelines (as mentioned above for PV and CSP).

7.2 Commissioning

The Commissioning tests shall be performed in the presence of the Grid Operator representative(s) and according to Grid Operator commissioning protocol to certify that the plant complies with the limits defined in this Code.

The Solar Plant Operator is responsible to submit to Grid Operator a Commissioning Plan and schedule (in accordance with Grid Operator protocol) within 30 business days from the approbation of the initial tests (i.e. reception of the *Clearance for Connection*). The Grid Operator shall approve the Commissioning Plan within 30 business days from its reception.

The commissioning of the electrical system shall include but not limited to the tests for proof of the following functionalities:

a) Set-point control of active power
b) Set-point control of reactive power
c) Frequency Withstanding and Ride through capabilities
d) Monitoring System Functionality test (in the case of LSSP this shall include SCADA connection)
e) Disconnection (normal and emergency)
f) Start-up after grid losses
g) Grid protection
h) Demonstration of satisfactory operation of the transformer cooling equipment in pooling substation.
i) Pressure tests on grid connection switchgear
j) Anti-islanding
k) Solar plant main and redundant communication testing

The right is reserved for the Grid Operator to request the Solar Plant Operator to perform additional tests which are deemed necessary to ensure integrity of the Grid, for which the Grid Operator must inform the Solar Plant Operator, in written, prior to the approval of the Commissioning Plan.

8 CHANGES AND MODIFICATIONS TO THIS CODE

Changes in this Code shall be proposed by Grid Operator and approved in written by EgyptERA.

9 REFERENCES

[1] Technical Requirements for Connecting Small Scale PV (ssPV) Systems to Low Voltage Distribution Networks, Jan 2014 – EgyptERA.

[2] IEEE Std 519-2014. IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems.

[3] IEC/TR 61000-3-7 ed2.0. Electromagnetic compatibility (EMC) - Part 3-7: Limits - Assessment of emission limits for the connection of fluctuating installations to MV, HV and EHV power systems.

[4] Egyptian Transmission Grid Code (Final sections 1 to 10).

10 ANNEXES

10.1 ANNEX I: Communications Requirements

10.1.1 Fibre Optic connection specification

a) The solar plant's fiber optic system shall contain terminal equipment equipped with E1(s) and optical line interface(s), primary multiplexer and associated digital teleportation.
b) The fiber optic equipment shall be based on the Synchronous Digital Hierarchy (SDH) technology, in compliance with ITU.T. G 707 recommendations for SDH STM-1 level (155M bit/s for both transmitter and receiver).
c) The SDH optical equipment shall perform both multiplexing and optical line terminating functions. All features and functions of the SDH multiplexer equipment shall be readily software configurable to suit operational requirements of the fiber optic communication system.
d) The SDH fiber optical equipment shall be housed in a cabinet and shall comprise, but not limited to the following function elements:
    i. Optical line interface
    ii. Tributary module
    iii. Switching unit
    iv. Alarm and Supervisory Facilities
    v. Engineering order wire (EOW) unit for service telephone
    vi. Service data interface
    vii. Power supply units
    viii. Electrical line interface
e) The rated power supply shall be 48 V DC.
f) The optical line interface shall carry out the parallel to serial conversion of the traffic from the switching unit into a STM- 1 stream, and be in compliance with ITU.T.G957 Recommendation.
g) The BER shall be 10-9 or better for received signal. It is preferable that the optical transmit and receive equipment are interconnected in such a way that a broken fiber will automatically switch off the optical transmitters at both ends.

10.1.2 Digital Power Line Carrier (DPLC) connection specification

a) The solar plant's DPLC system shall contain multiplexers PLC equipment and associated teleprotection tone equipment, wave traps, coaxial cable, CCVT and line matching units.
b) The DPLC system shall be coupled with transmission line using Coupling Capacitor Voltage Transformer (CCTV) and on the other side shall have a gateway with RS 232 port toward the solar plant controlling system.
c) The Wave Traps and Line Matching Units are to be used for inter-circuit coupling on one phase of HV line.
d) The wave traps shall conform to IEC 353 standards, with nominal rated current of 2000 Amps, thermal short circuit rating not less than 50 kA/1sec, and resistive impedance not less than 600 OHM.
e) The line Matching Unit shall conform to IEC-481 standards, and shall be provided with safety assembly which consists of: earthing switch, drainage coil and surge arrestor.
f) The coaxial armor cable shall connect the digital power line carrier (DPLC) in the communication room to the line-matching units (LMU), including the terminating connectors.

g) The cable shall conform to IEC 255 testing standards with test voltage greater than 6 KV and attenuation less than at 2.5 dB/Km at 200 KHz.

10.2 Annex-II: Standards and Norms

EN 50380	Datasheet and nameplate information of photovoltaic module.
EN 50521	Connectors for photovoltaic systems - Safety.
EN 50524	Data sheet and name plate for photovoltaic inverters
IEC 60068-2	Environmental testing of specimen to withstand specific severities of repetitive and non- repetitive nature
IEC 60076	Power transformers
IEC 60085	Electrical Insulation – Thermal Evaluation and Designation
IEC 60214-1	Tap-changers –Performance requirements and test methods
IEC 60227	Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V.
IEC 60228	Conductors of Insulated Cables
IEC 60364-1	Electrical installations of buildings - Part 1: Scope, object and fundamental principles
IEC 60364-5-54	Electrical installations of buildings. Part 5: Selection and erection of electrical equipment. Chapter 54: Earthing arrangements and protective conductors
IEC 60364-5-55	Electrical installations of buildings
IEC 60364-6	Verification of Low-voltage electrical installations
IEC 60502-1	Power Cables with extruded insulation and their accessories for rated voltages from 1 kV (Um – 1.2 kV) up to 30 kV (Um = 36 kV) Part 1 - Cables for rated voltages for 1 kV (Um=1.2 kV) and 3
IEC-60870-5-101	Transmission Protocols
IEC 60904-1	Photovoltaic devices: Part 1 Measurement of Photovoltaic current-voltage characteristics
IEC 60909-1	Short circuit calculation in three-phase ac systems.
IEC 60947	Connectors for photovoltaic systems - Safety.
IEC 61000-3-3	Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤ 16 A per phase and not subject to conditional connection
IEC 61000-3-7	Assessment of emission limits for the connection of the connection of fluctuating installations to MV, HV and EHV power systems.
IEC 61000-6-1	Generic standard -EMC - Susceptibility - Residential, Commercial and Light industry
IEC 61000-6-3	Generic standard - EMC - Emissions - Residential, Commercial and Light industry
IEC 61215	Crystalline silicon terrestrial photovoltaic (PV) modules - Design qualification and type approval
IEC 61439	Low-voltage switchgear and controlgear assemblies
IEC 61683	Photovoltaic systems - Power conditioners - Procedure for Measuring Efficiency
IEC 61724	Photovoltaic system performance monitoring – Guidelines for measurement, data exchange and analysis
IEC 61727	Photovoltaic (PV) systems - Characteristics of the utility interface

IEC 61730	Photovoltaic (PV) module safety qualification
IEC 61836	Solar photovoltaic energy systems - Terms, definitions and symbols
IEC 61850	Design of electrical substation automation
IEC 61853-1	Photovoltaic (PV) module performance testing and energy testing – Part 1: Irradiance and temperature performance measurements and power rating
IEC 62056	DLMS/COSEM Standards
IEC 62093	Balance-of-system components for photovoltaic systems
IEC 62109 -1/2	Safety of power converters for use in photovoltaic power systems
IEC 62116	Test procedure of islanding prevention measures for utility-interconnected photovoltaic inverters.
IEC 62271	High-voltage switchgear and controlgear
IEC 62305-3	Protection against lightning, part 3 physical damage and life hazards in structures
IEC 62446	Grid connected photovoltaic systems - Minimum requirements for system documentation, commissioning tests and inspection
IEEE 519-1992	Recommended practices and requirements for harmonic control in electric power systems
ISO 9060/1990	Solar energy -- Specification and classification of instruments for measuring hemispherical solar and direct solar radiation
IEEE P1547	Series of Standards for Interconnection, May, 2003, NREL/CP-560-34003
IEEE C37.90	IEEE Standard for Relays and Relay Systems Associated with Electric Power Apparatus
BS 7354	Code of Practice for Design of high voltage open terminal stations
BS 7430	Code of Practice for Protective Earthing of electrical installations
EN 12975	Thermal solar systems and components – Solar collectors - Part 2: Test methods
UNE 206010	Tests for verifying the performance of solar thermal power plants with cylindrical parabolic trough collector technology
NREL/SR-5500-48895	Utility-Scale Parabolic Trough Solar Systems: Performance Acceptance Test Guidelines
NREL/SR-5500-57272	Utility-Scale Power Tower Solar Systems: Performance Acceptance Test Guidelines
ASTM E905	Standard Test Method for Determining Thermal Performance of Tracking Concentrating Solar Collectors.