SMA Solar Technology AG

Solar Inverters

MLX Series

Design Guide

www.SMA.de

Contents

1 Introduction

1.1 Introduction

The Design Guide provides information required for planning and dimensioning an installation. It describes requirements for use of the MLX series inverters in solar energy applications.

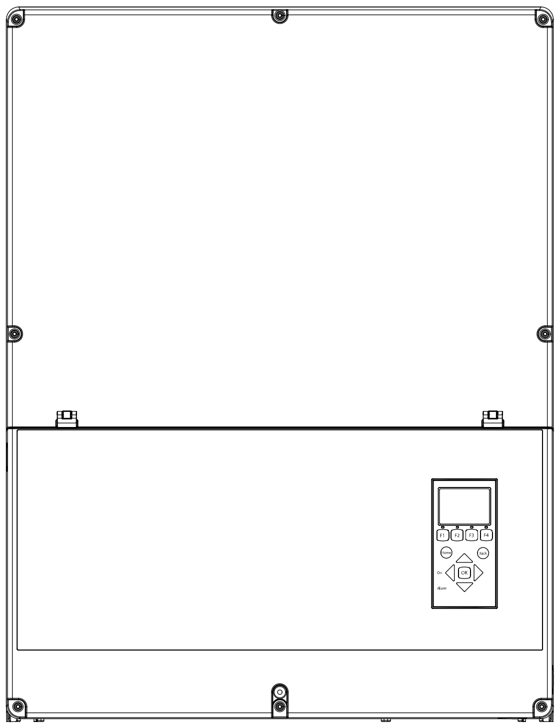


Illustration 1.1 MLX Inverter

Additional resources available:

- *Installation Guide*, supplied with the inverter, for information required to install and commission the inverter
- *Inverter Manager Installation Poster*, for information required to install the Inverter Manager
- *Inverter Manager Assembly Installation Guide*, for information required to install the Inverter Manager Assembly
- *Fan Installation Instruction*, for information required to replace a fan
- *SPD Installation Instruction*, for information required to replace Surge Protection Devices

These documents are available from the download area at www.sma.de, or from the supplier of the solar inverter.

Additional application-specific information is available at the same location.

1.2 List of Abbreviations

Abbreviation	Description
ANSI	American National Standards Institute
AWG	American Wire Gauge
cat5e	Category 5 twisted pair cable (enhanced)
DHCP	Dynamic Host Configuration Protocol
DNO	Distribution Network Operator
DSL	Digital Subscriber Line
EMC (Directive)	Electromagnetic Compatibility Directive
ESD	Electrostatic Discharge
FCC	Federal Communications Commission
FRT	Fault Ride Through
GSM	Global System for Mobile Communications
HDD	Hard Disk Drive
IEC	International Electrotechnical Commission
IT	Isolated Terra
LCS	Local Commissioning and Service
LED	Light-Emitting Diode
LVD (Directive)	Low Voltage Directive
MCB	Miniature Circuit Breaker
MPP	Maximum Power Point
MPPT	Maximum Power Point Tracking
NFPA	National Fire Protection Association
P	P is the symbol for active power and is measured in Watts (W).
PCB	Printed Circuit Board
PCC	Point of Common Coupling The point on the public electricity network to which other customers are, or could be, connected.
PE	Protective Earth
PELV	Protected Extra-Low Voltage
PLA	Power Level Adjustment
P_{NOM}	Power [W], Nominal conditions
POC	Point of Connection The point at which the PV system is connected to the public electricity grid.
P_{STC}	Power [W], Standard Test Conditions
PV	Photovoltaic, photovoltaic cells
RCD	Residual-Current Device
RCMU	Residual Current Monitoring Unit
R_{ISO}	Insulation Resistance
ROCOF	Rate Of Change Of Frequency
Q	Q is the symbol for reactive power and is measured in reactive volt-amperes (VAr).
S	S is the symbol for apparent power and is measured in volt-amperes (VA).

Abbreviation	Description
STC	Standard Test Conditions
SW	Software
THD	Total Harmonic Distortion
TN-S	Terra Neutral - Separate. AC Network
TN-C	Terra Neutral - Combined. AC Network
TN-C-S	Terra Neutral - Combined - Separate. AC Network
TT	Terra Terra. AC Network

Table 1.1 Abbreviations

2 Inverter Overview

2.1 Product Label

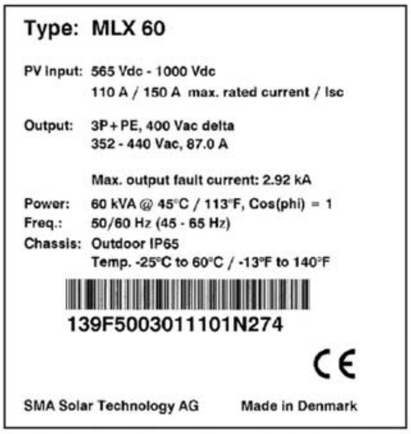


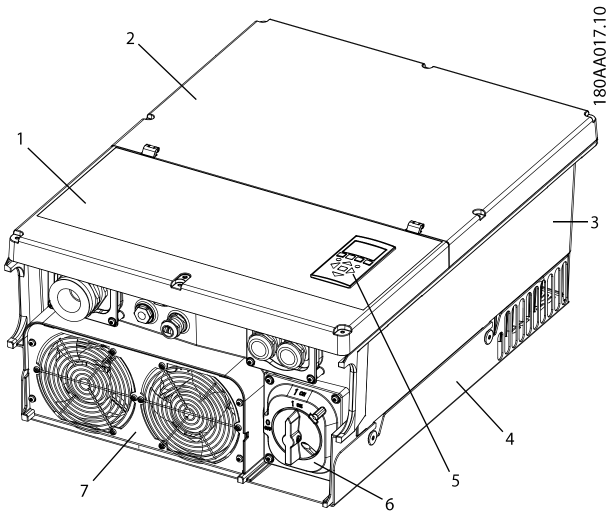
Illustration 2.1 Product Label MLX 60

Illustration 2.2 Product Label MLX 60 UL

The product label on the side of the inverter shows:

- Inverter type
- Important specifications
- Serial number, located under the bar code, for inverter identification

2.2 Mechanical Overview of the Inverter



1	Cover for installation area
2	Front cover
3	Die-cast aluminium heat sink
4	Mounting plate
5	Display (read-only)
6	PV load switch (optional)
7	Fans

Illustration 2.3 Mechanical Overview of the Inverter

2.3 Description of the Inverter

Inverter features:

- IP65 enclosure/Type 3R
- PV load switch
- Ancillary service functionalities
- Transformerless
- 3-phase
- 3-level inverter bridge with a high performance
- Integrated residual current monitoring unit.
- Insulation test functionality.

- Extended fault ride through capabilities (to support reliable power generation during grid faults) - depending on inverter configuration
- Compliant with a wide range of international grids
- Adapted to local requirements and conditions via grid code setting

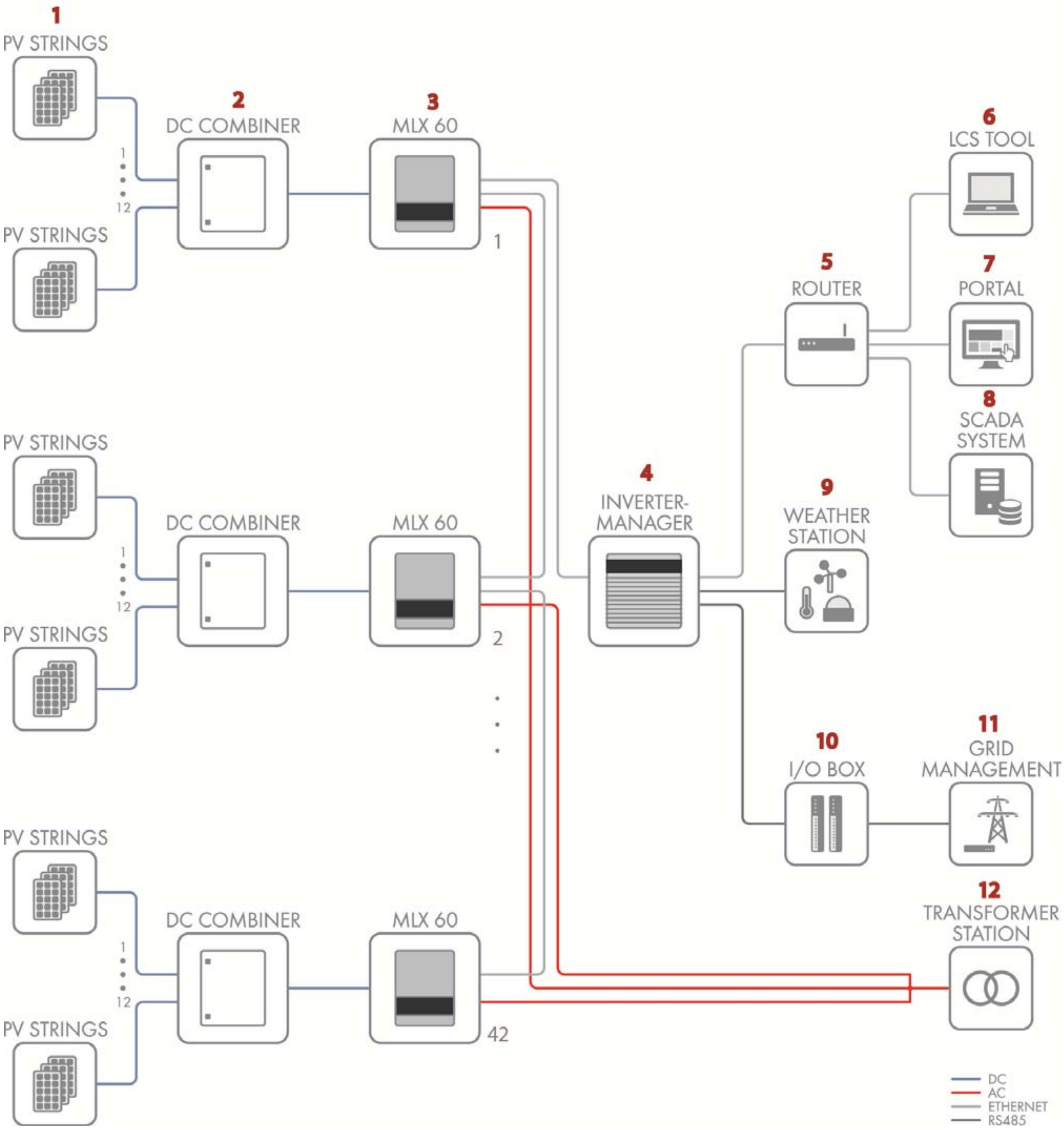
2.3.1 System Overview

The MLX system draws on the advantages of both string inverters and central inverters, making it highly applicable in many commercial and utility scale plants.

The MLX system consists of the MLX inverter itself, a DC string combiner and the Inverter Manager.

The communication network of an MLX system is divided into 2 Ethernet networks; Plant network and inverter network. The plant network is the communication interface to the MLX plant and may be shared by several Inverter Managers as well as other IT equipment, while the inverter network is solely used for MLX inverters. The plant network must have a DHCP server (router) as the Inverter Manager requires automatic IP assignment. It is recommended to use professional grade routers and switches. The Inverter Manager provides:

- Control of up to 42 MLX inverters
- Single point of access for each (up to) 2.5 MVA plant for simple plant network deployment
- Easy commissioning and service of the plant using the Local Commissioning and Service (LCS) tool
- Safe upload to data warehouse services, and control of all local requirements and settings from the DNO
- Open source Modbus TCP communication protocol using SunSpec Alliance profile via Ethernet both for monitoring and control, making it easy to integrate in e.g. SCADA systems
- Grid management interface through the optional I/O box for PLA and reactive power commands
- Easy integration of meteorological data using an RS-485 SunSpec Alliance compliant weather station



1	PV strings
2	DC combiner
3	MLX inverter
4	MLX Inverter Manager
5	Router
6	LCS tool
7	Portal
8	SCADA system
9	Weather station
10	I/O box
11	Grid management
12	Transformer station

Illustration 2.4 System Overview

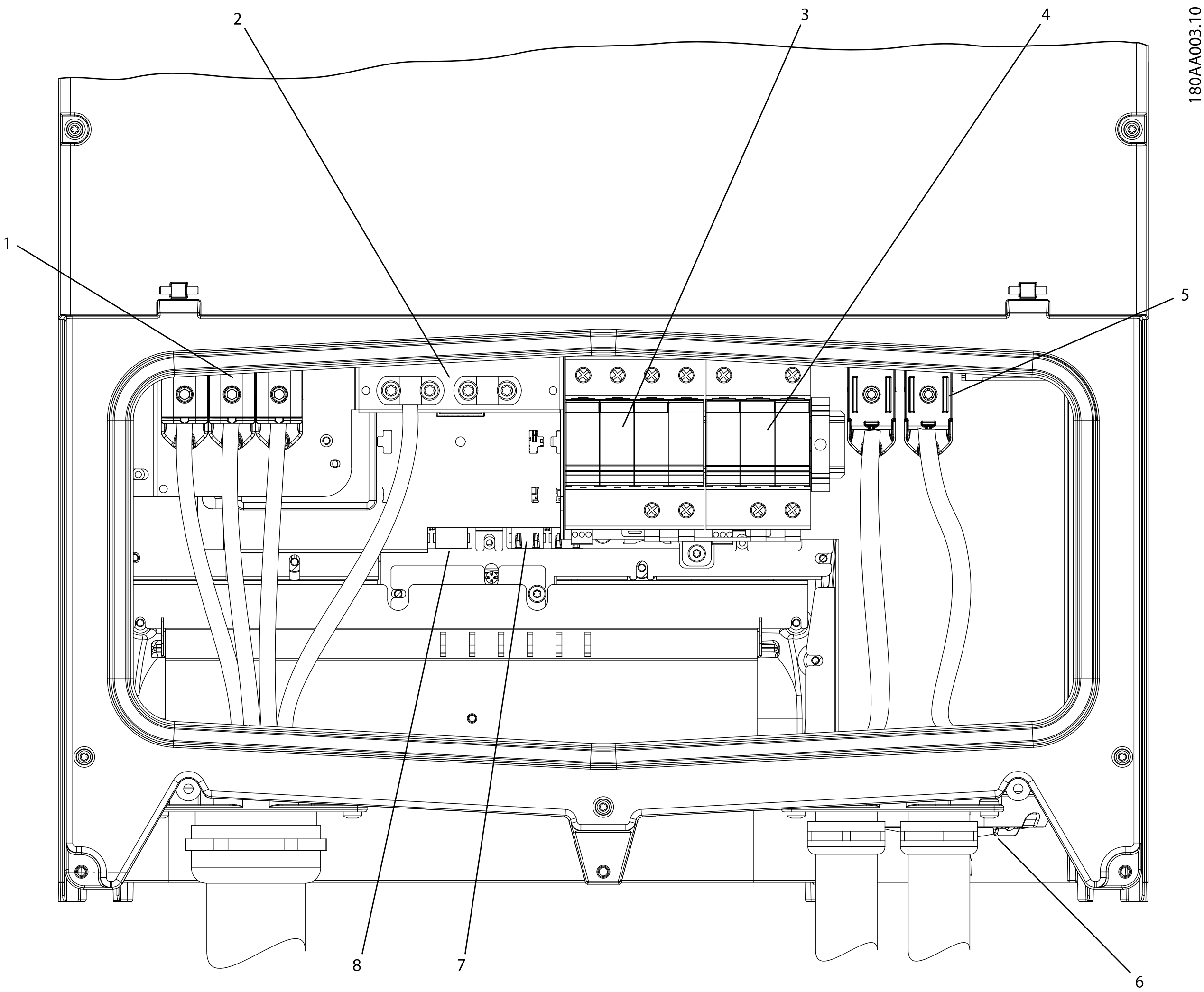


Illustration 2.5 Overview of Installation Area

PELV (Safe to touch)	
2	Equipment grounding
7	Ethernet interface x 2
8	RS-485 interface (not in use)
Live Part	
1	AC connection terminals
5	PV connection terminals
Other	
3	Surge Protection AC
4	Surge Protection DC
6	PV load switch (optional)

2.3.2 Functional Safety

The inverter is designed for international use, with functional safety circuit design meeting a wide range of international requirements (see *2.5 Grid Code*).

Single-fault Immunity

The functional safety circuit has a fully redundant built-in single-fault detection. If a fault occurs, the inverter disconnects from the grid immediately. The method is active and covers all circuitry within the residual current monitoring, both for continuous levels and sudden changes. All functional safety circuits are tested during start-up to ensure safe operation. If a circuit fails more than 1 out of 3 times during the self-test, the inverter enters fail safe mode. If the measured grid voltages, grid frequencies, or residual current during normal operation differ too much between the 2 independent circuits, the inverter ceases to energise the grid and repeats the self-test. The functional safety circuits are always activated and cannot be disabled.

Isolation

During the self-test, the inverter has an isolation measuring system that detects whether the isolation in the PV system is above the required level. This is done before the inverter starts to energise the grid. During grid connection, the inverter measures the continuous leakage current in the system. If this level is exceeded more than 4 times during 24 hours, the inverter stops operating due to safety hazards in the PV system.

NOTICE

Depending on the local legislation, a minimum earth-to-PV isolation resistance is defined. A typical value is 82 kΩ.

Self-test
The insulation resistance between the PV arrays and earth is also tested during the self-test. The inverter does not energise the grid if the resistance is too low. It then waits 10 minutes before making a new attempt to energise the grid.

Residual current
Residual current is continuously monitored. The inverter ceases to energise the grid when:

- The cycle RMS value of the residual current violates the trip settings for more than the duration of 'clearance time', or
- A sudden jump in the residual current is detected

Grid Surveillance
Grid-related parameters are under constant surveillance when the inverter energises the grid. The following is monitored:

- Grid voltage magnitude (instantaneous and 10 minute average)
- Grid voltage and frequency
- Loss of Mains (Islanding detection):
    - 3-phase Loss of Mains (LoM) detection
    - Rate of Change of Frequency (ROCOF)
    - Frequency shift.
- DC content of grid current
- Residual current by means of RCMU

The inverter ceases to energise the grid if one of the parameters violates the grid code.

2.3.3 Operation Modes

The inverter has 5 operation modes, indicated by LEDs.

Status	LEDs	
Off grid	Green	- - - - - - - - - - - - - - - -
	Red	- - - - - - - - - - - - - - - -
Connecting	Green	
	Red	- - - - - - - - - - - - - - - -
On grid	Green	
	Red	- - - - - - - - - - - - - - - -
Internal inverter event	Green	
	Red	- - - - - - - - - - - - - - - -
Fail safe	Green	- - - - - - - - - - - - - - - -
	Red	

Table 2.1

Off grid (standby) (LEDs off)
#0-51.
When no power has been delivered to the AC grid for more than 10 minutes, the inverter disconnects from the grid and shuts down. User and communication interfaces remain powered for communication purposes.

Connecting (Green LED flashing)
#52-53.
The inverter starts up when the PV input voltage reaches the minimum DC feed-in voltage. The inverter performs a series of internal self-tests, including measurement of the resistance between the PV arrays and earth. Meanwhile, it also monitors the grid parameters. When the grid parameters have been within the specifications for the required amount of time (depends on grid code), the inverter starts to energise the grid.

On grid (Green LED on)
#60.
The inverter is connected to the grid and energises the grid. The inverter disconnects when:

- it detects abnormal grid conditions (dependent on grid code), or
- an internal event occurs, or
- PV power is insufficient (no power is supplied to the grid for 10 minutes)

The inverter then enters connecting mode or off grid mode.

Internal Inverter Event (Green LED flashing)
#54
The inverter is waiting for an internal condition to become within limits (for example a too high temperature) before it will go back on grid.

Fail Safe (Red LED flashing)
#70.
If the inverter detects an error in its circuits during the self-test (in connecting mode) or during operation, the inverter goes into fail safe mode, disconnecting from grid. The

inverter will remain in fail safe mode until power has been absent for a minimum of 10 minutes, or the inverter has been shut down completely (AC+PV).

2.4 MPP Tracker and Derating

2.4.1 MPP Tracker

The Maximum Power Point Tracker (MPPT) is an algorithm, which is constantly trying to maximise the output from the PV array. The algorithm updates the PV voltage fast enough to follow rapid changes in solar irradiance. The MPPT will find the maximum power point while the PV voltage is within the specified MPP voltage range. At voltages below the minimum MPP voltage of the inverter, the MPPT moves away from the maximum power point (see *Illustration 2.6*) in order to maintain sufficient DC voltage to generate the required AC grid voltage.

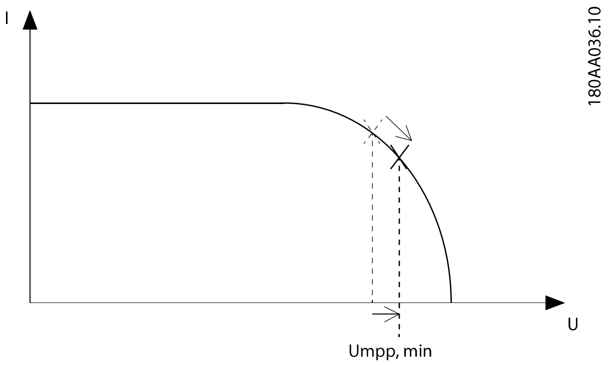


Illustration 2.6 MPPT Behaviour at Low MPP Voltage

NOTICE

Due to the boosterless design of the MLX inverter, the minimum MPP voltage varies with the actual AC grid voltage.

2.4.2 Inverter Derating

In certain situations, the MPPT purposely moves away from the maximum power point. This behaviour is called derating and is a means of protecting the inverter against overload or a reduction of output power in order to support the grid. Reactive power (supporting the grid) has priority when the derate function is reducing the AC output power, meaning that first active power is reduced to zero where after reactive power is reduced. The MLX system is derating in the following situations:

- Exceeding max AC power rating
- Internal over temperature
- Grid over voltage
- Grid over frequency
- AC power limitation by setting or external command (PLA)

Each MLX inverter limits the AC output power according to the actual power reference, which will be the lowest of the following values:

- Max AC power rating (60 kVA)
- Fixed active/reactive power limit set by grid code file
- Active/reactive power reference from the Inverter Manager
- Power limit from internal temperature derating. Derating due to temperature is a sign of excessive ambient temperature, a dirty heat sink, a blocked fan or similar. Refer to the *MLX Installation Guide* regarding maintenance. The values shown in *Illustration 2.7* are measured at nominal conditions cos(φ) = 1

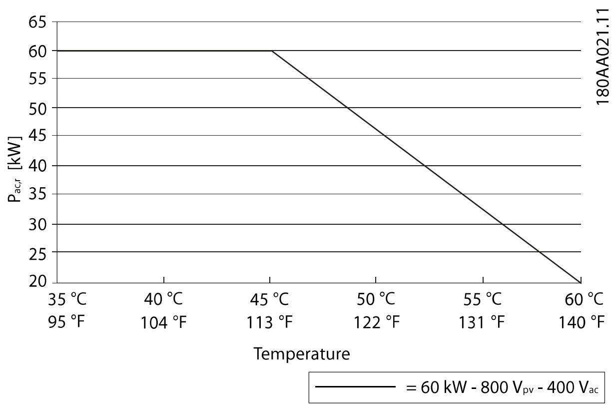


Illustration 2.7 Derating as Function of Internal Overtemperature

NOTICE

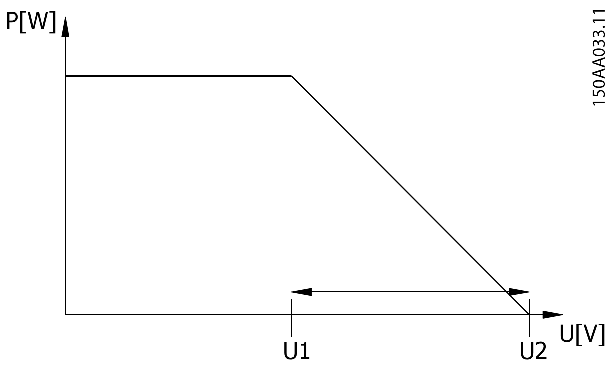
The inverter can use the entire admissable DC voltage range up to 1000 V for derating. It is not restricted to the MPP voltage range.

2.4.3 Power Reference

The power reference for the individual MLX inverter is generated by the Inverter Manager based on the following functions. They are all deployed in the Inverter Manager and thus calculated on plant level.

- **Grid Overvoltage**
  When the grid voltage exceeds a DNO-defined limit U1, the inverter derates the output power. If the grid voltage increases and exceeds the defined limit 10 min mean (U2), the inverter ceases to energise the grid, in order to maintain

power quality and protect other equipment connected to the grid.



U1	Fixed
U2	Trip Limit

Illustration 2.8 Grid Voltage above Limit Set by DNO

Derating - Grid Over-frequency
The output power is reduced as a variable of the grid frequency. There are 2 methods for reducing the output power: ramp and hysteresis. The grid code setting determines which method is implemented in a specific installation.

Primary frequency control – ramp method
See *Illustration 2.9*.
The inverter reduces output power if the grid frequency exceeds f1. Reduction occurs at a preconfigured rate, which is the ramp (R) shown in *Illustration 2.9*. When the frequency reaches f2, the inverter disconnects from grid. When the frequency decreases below f2, the Inverter reconnects to grid and ramps up power at the same rate as for the reduction.

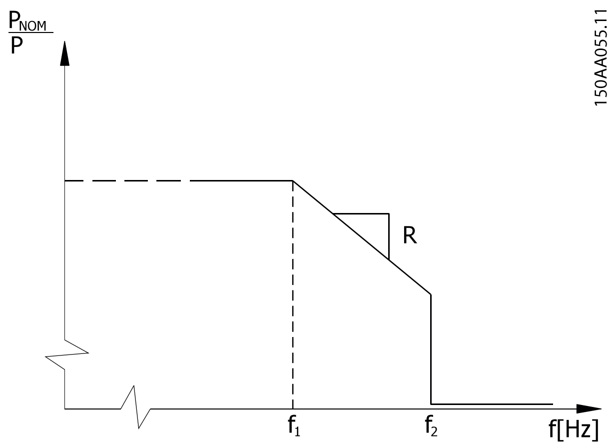


Illustration 2.9 Primary Frequency Control – Ramp Method

Primary frequency control - hysteresis method
See *Illustration 2.10*.
To support grid stabilisation, the inverter reduces output power if the grid frequency exceeds f1. Reduction occurs at a preconfigured rate, which is the ramp (R) shown in *Illustration 2.10*. The reduced output power limit is maintained until the grid frequency has decreased to f2. When the grid frequency has decreased to f2, the inverter output power increases again following a time ramp T. If the grid frequency continues to increase, the inverter disconnects at f3. When the frequency decreases below f2, the inverter reconnects to grid and ramps up power at the same rate as for the reduction.

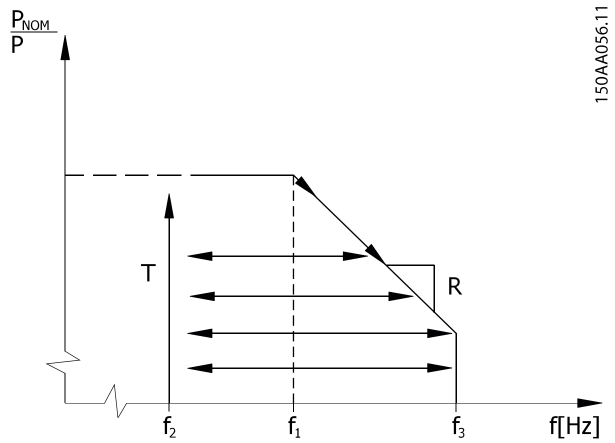


Illustration 2.10 Primary Frequency Control – Hysteresis Method

2.5 Grid Code

The MLX grid code file contains settings that determine both the behaviour of the single inverter and the entire plant. The grid code file is divided into 2 main sections:

- Grid protection settings
- Grid support (ancillary services)

The LCS tool used for commissioning the inverter is equipped with a range of default grid codes to meet national requirements. Changing these default grid code parameters requires a customised grid code file, supplied by SMA. See *2.7 Functional Safety Settings* about how to apply for customised grid code parameters.

NOTICE

Obtain approval from the local distribution network operator (DNO) before connecting the inverter to the grid.

2.5.1 Grid Protection Settings

The grid protection settings are stored in each inverter. They ensure protection of the grid in case of certain grid events regardless of the connection to the Inverter Manager. The inverter continuously monitors the following grid values, and compares them to the disconnection values specified in the grid code. Example:

- Voltage disconnection
- Frequency disconnection
- Reconnection
- Loss of mains

Voltage and frequency disconnection
The cycle RMS values of the grid voltages are compared with 2 lower and 2 upper trip settings, for example overvoltage (stage 1). If the RMS values violate the trip settings for more than the duration of 'clearance time', the inverter ceases to energise the grid.

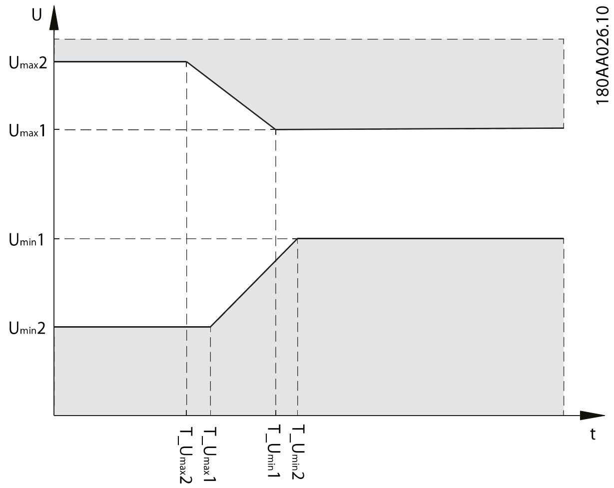


Illustration 2.11 Overvoltage and Undervoltage Disconnect

Reconnection
During start-up or when the inverter has disconnected from grid due to for example overvoltage or frequency, the reconnection values determine under which grid conditions the inverter can reconnect to the grid and start injecting energy.

Loss of Mains (Islanding) disconnection
Loss of Mains (LoM) is detected by 3 different algorithms:

- 3-phase voltage surveillance (the inverter has individual control of the 3-phase currents). The cycle RMS values of the phase-phase grid voltages are compared with a lower trip setting or an upper trip setting. If the RMS values violate the trip settings for more than the duration of 'clearance time', the inverters cease to energise the grid
- Rate of change of frequency (ROCOF). The ROCOF values (positive or negative) are compared to the trip settings. The inverter ceases to energise the grid when the limits are violated
- Frequency shift. The inverter continuously tries to 'push' the grid frequency a bit, but the stability of the grid prevents this from happening

In an LoM situation, the stability of the grid is no longer present, and this makes it possible to change the frequency. As the frequency deviates from the operational frequency of the line, the inverter disconnects and ceases to energise the grid. If the inverter ceases to energise the grid due to grid frequency or grid voltage (not 3-phase LoM), and if the frequency or voltage is restored within a short time (short interruption time), the inverter can reconnect when the grid parameters have been within their limits for the specified time (reconnect time). Otherwise, the inverter returns to the normal connection sequence.

2.6 Grid Support (Ancillary Services)

The ancillary services are comprised in 2 main categories:

- Fault Ride Through (FRT).
- Reactive and active power management.

2.6.1 Fault Ride Through

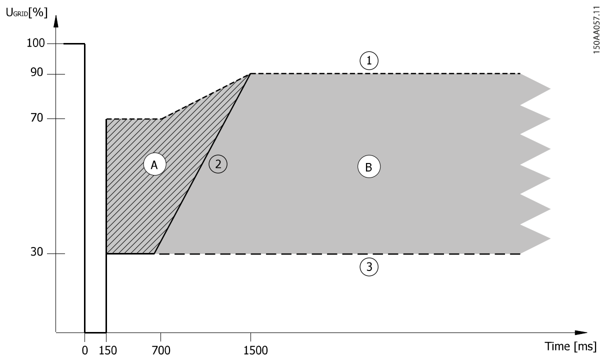
The grid voltage usually has a smooth waveform, but occasionally the voltage drops or disappears for several milliseconds. This is often due to short circuit of overhead lines, or caused by operation of switchgear or similar in the high-voltage transmission lines. In such cases, the inverter can continue to supply power to the grid using fault ride through (FRT) functionality. Continuous power supply to the grid is essential:

- To help prevent a complete voltage blackout and stabilise the voltage in the grid.
- To increase the energy delivered to the AC grid.

There are 4 different behaviours to select from:

- Zero Current
- Reactive current only
- Active current only
- Full current – reactive priority

How FRT works
Illustration 2.12 shows the requirements that must be followed by FRT. The example is for German medium-voltage grids.



Above line 1	For voltages above line 1, the inverter must not under any circumstances disconnect from the grid during FRT.
Area A	The inverter must not disconnect from grid for voltages below line 1 and left of line 2. In some cases, the DNO permits a short-duration disconnection, in which case the inverter must be back on grid within 2 s.
Area B	Right of line 2, a short-duration disconnection from grid is always permitted. The reconnect time and power gradient can be negotiated with the DNO.
Below line 3	Below line 3 there is no requirement to remain connected to grid.

Illustration 2.12 German Example

When a short-duration disconnection from grid occurs:

- The inverter must be back on grid after 2 s
- The active power must be ramped back at a maximum rate of 10% of nominal power per s

Active power management
The inverter can support the local grid by either static or dynamic limit of the plant output power. The different methods of control are:

- Fixed Pref – maximum active power limit
- Power Level Adjustment (PLA) – remotely controlled maximum active power limit (requires I/O box)

2.6.2 Reactive Power Management

Reactive power management
The inverter can support the local grid voltage by injecting reactive power. The different control methods are:

Q(U)	Reactive power injected as a function of the grid voltage.
Q(P)	Reactive power injected as a function of the active output power.
Q(S)	Reactive power injected as a function of the apparent output power.
Q(T)	Reactive power injected as a function of the ambient temperature.
PF(P)	Power factor as a function of active output power.
PF(T)	Power factor as a function of the ambient temperature.
PFext	Power factor according to external signal either via Modbus or the external I/O box (RS-485).
Qext	Reactive power injected according to external signal either via Modbus or the external I/O box (RS-485).

Table 2.2 Reactive Power Management, Control Methods

NOTICE

Only 1 method can be used at a time. A mode selector determines which method to activate.

With the setpoint curve Q(U), the inverter controls reactive power as a function of the grid voltage U. The values for the setpoint curve are determined by the local utility company and must be obtained from them (see *Illustration 2.13*).

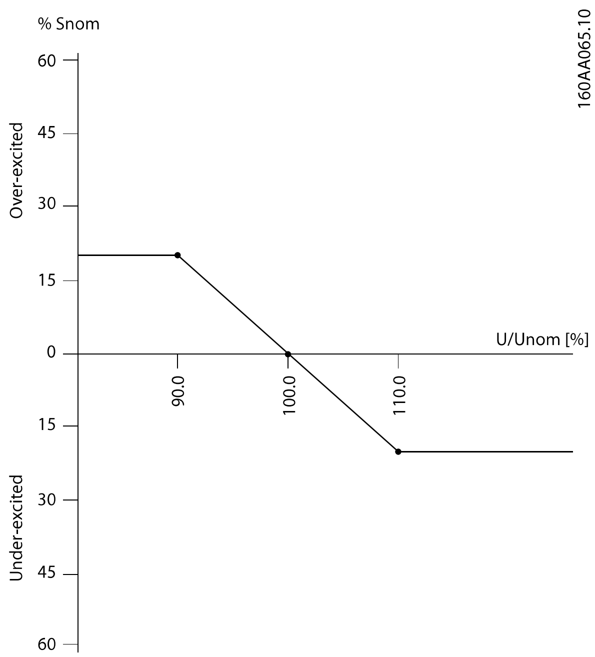
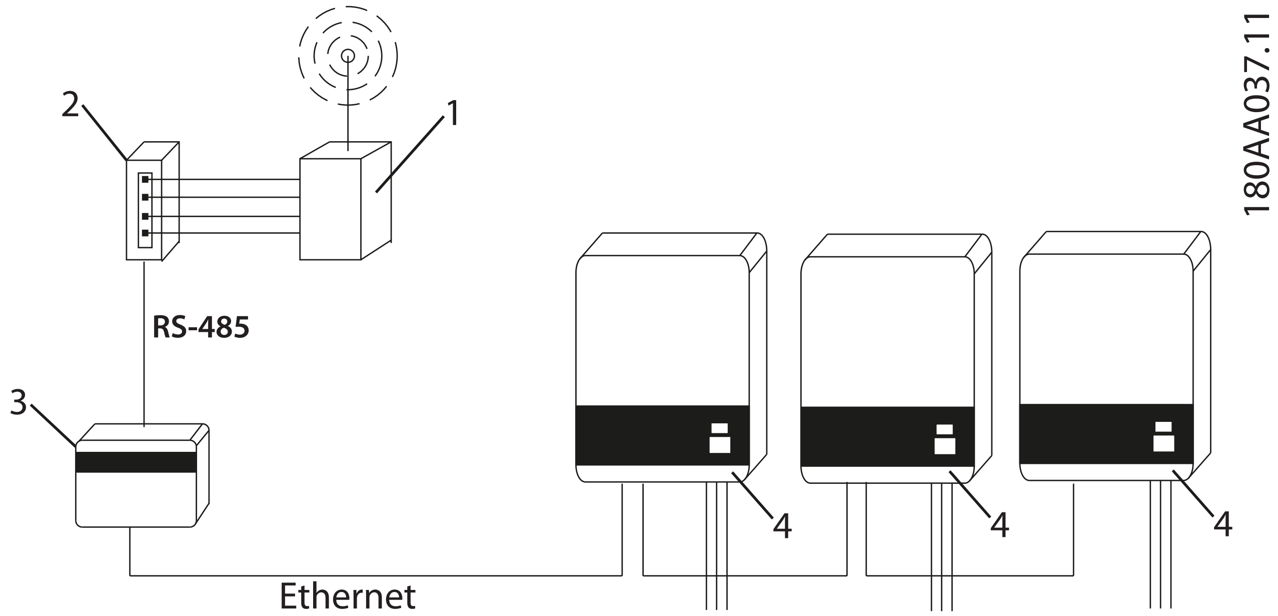


Illustration 2.13 Q(U) Setpoint Curves - Reactive Power

When the grid voltage is below nominal, the inverter is configured to inject over-excited reactive power in order to help increase the grid voltage back up to nominal. When the grid voltage is above nominal, the inverter injects under-excited reactive power to help decrease grid voltage and thus supports the grid by maintaining a more stable and healthy voltage.

Qext. and PFext
Control of a plant's reactive power injection can be handled remotely with I/O box via RS-485 or via a 3rd-party external signal via Modbus.

I/O box
The I/O box monitors the relay state of the Ripple control receiver (supplied by the DNO) and transmits the state to the Inverter manager via RS-485. The Inverter Manager translates the relay state into the corresponding PLA value (max. plant output power) based on the grid code configuration.



1	Ripple Control Receiver
2	I/O Box
3	Inverter Manager
4	MLX

Illustration 2.14

External signal (3rd party)
Modbus SunSpec control profile can be used to control the reactive power injected by the plant.

2.6.3 Active Power Management

Apparent power management
The inverter can support the local grid by setting a maximum apparent power limit.

- Fixed Sref – maximum apparent power limit

Fallback
The inverters in the inverter network are controlled by a Qref and Pref from the Inverter Manager. If the connection to the Inverter Manager is lost, the inverter disconnects from grid after up to 40 seconds. If the connection is restored within this period the inverter will not disconnect from grid. When the connection is restored, the inverters reconnect to grid.

2.7 Functional Safety Settings

The inverter is designed for international use and it can handle a wide range of requirements related to functional safety and grid behaviour. Parameters for functional safety are predefined and do not require any alteration during installation. However, some grid code parameters may require alterations during installation to allow optimisation of the local grid. Contact SMA for a custom grid code.

3 System Planning – Mechanical

The aim of this section is to provide general information for planning the mechanical installation of the MLX inverter, including mounting and cable specifications.

3.1 Unpacking

Contents:

- Inverter
- Mounting plate
- Accessories bag, containing:
  - 6 wall plugs 8 x 50 mm
  - 6 mounting screws 6 x 60 mm
  - 1 M25 cable gland with sealing grummet for Ethernet cables
  - 2 conduit brackets (2 inches - only for UL version)
  - 1 equipment grounding bolt 6 x 12 mm
- Installation guide, booklet format
- Quick guide, poster format

3.2 Installation

Illustration 3.1 Avoid Constant Stream of Water

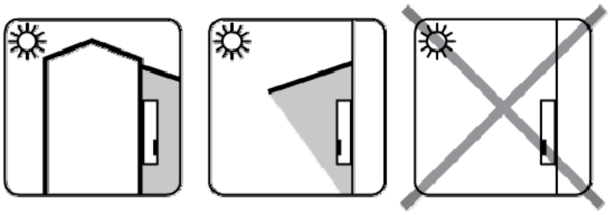


Illustration 3.2 Avoid Direct Sunlight

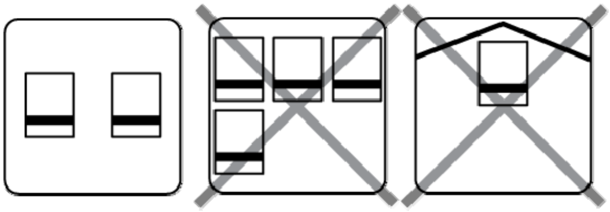


Illustration 3.3 Ensure Adequate Air Flow

Illustration 3.4 Ensure Adequate Air Flow

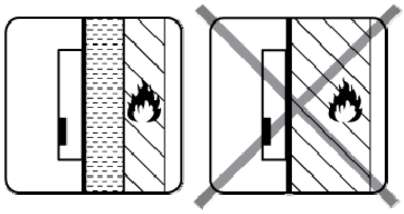


Illustration 3.5 Mount on Non-flammable Surface

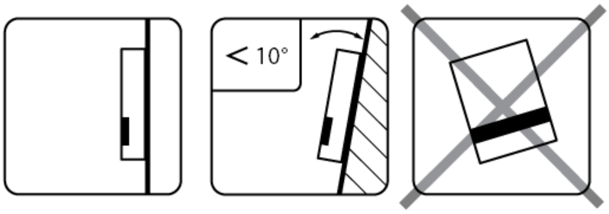


Illustration 3.6 Mount Upright on Vertical Surface. Tilt of up to 10 degrees is permitted

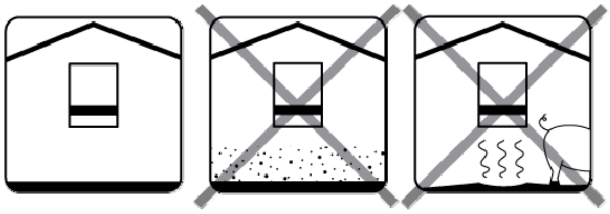


Illustration 3.7 Prevent Dust and Ammonia Gases

NOTICE

When planning the installation site, ensure that inverter product and warning labels remain visible. For details, refer to *6 Technical Data*.

3.2.1 Installation Conditions

Parameter	Specification
Operational temperature range	−25 °C – +60 °C (possible power derating above 45 °C) (−13 °F – 140 °F) (possible power derating above 113 °F)
Storage temperature	−40 °C – +60 °C (−40°F – 140 °F)
Relative humidity	95% (non-condensing)
Environmental class according to IEC 60721-3-4	4K4H/4Z4/4B2/4S3/4M2/4C2
Cooling concept	Forced
Air quality - general	ISA S71.04-1985 Level G3 (at 75% RH)
Air quality - coastal, heavy industrial and agricultural zones	Must be measured and classified acc. to ISA S71.04-1985: G3 (at 75% RH)
Vibration	1G
Enclosure rating ingress protection class	IP65
UL 50E enclosure type	Type 3R
Max. operating altitude	2000 m (6500 ft) above sea level (derating may occur at an altitude over 1000 m).
Installation	Avoid constant stream of water. Avoid direct sunlight. Ensure adequate air flow. Mount on non-flammable surface. Mount upright on vertical surface. Prevent dust and ammonia gases.

Table 3.1 Conditions for Installation

Parameter	Condition	Specification
Mounting plate	Hole diameter	30 x 9 mm
	Alignment	Perpendicular ±10° all angles

Table 3.2 Mounting Plate Specifications

3.3 Mounting the Inverter

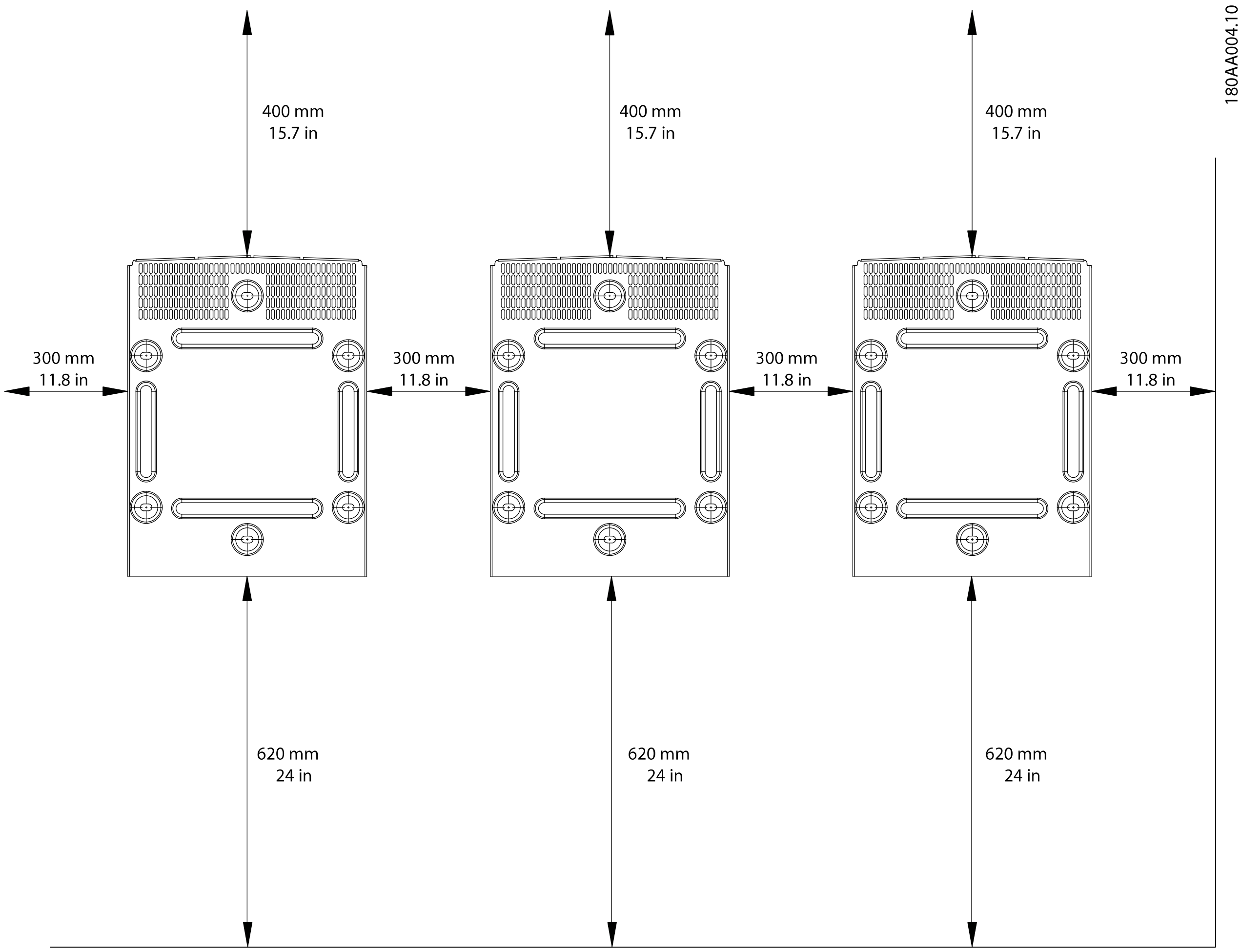


Illustration 3.8 Safe Clearances

NOTICE

Ensure 620 mm/24 inches base clearance for adequate airflow.

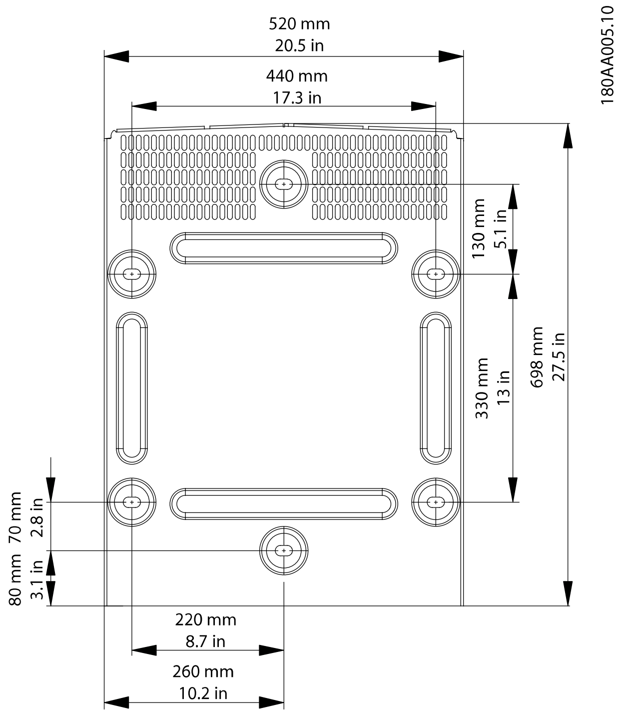


Illustration 3.9 Mounting Plate

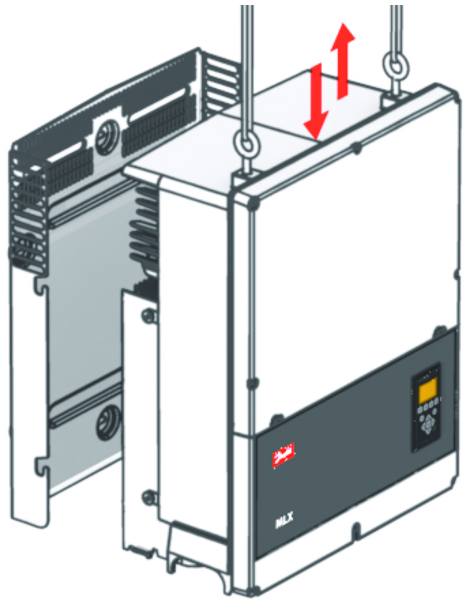


Illustration 3.10 Position the Inverter

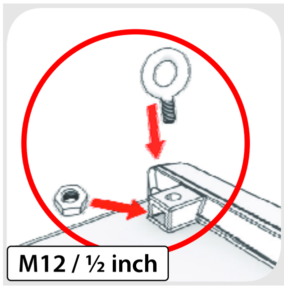


Illustration 3.11 Lifting Bolts

NOTICE

Use of the mounting plate delivered with the inverter is mandatory. If the inverter is mounted without the mounting plate, the warranty becomes void. It is strongly recommended to use all 6 mounting holes.

Important when mounting the mounting plate:

- Mount in the defined environment
- Use screws and rawl plugs that can safely carry the weight of the inverter
- Ensure that the mounting plate is correctly aligned
- Observe safe clearances when installing 1 or more inverters, to ensure adequate airflow. Clearances are specified in *Illustration 3.8* and the mounting plate label
- Mounting multiple inverters in a single row is recommended. Contact the supplier for guidelines when mounting inverters in more than 1 row
- Ensure adequate clearance at the front, for service access to the inverter

3.3.1 How to Position the Inverter

Use M12 or ½ in lifting bolts and matching nuts (not supplied in the accessories bag) for mounting.

CAUTION

Refer to local health and safety regulations when handling the inverter.

3.3.2 Torque Specifications for Installation

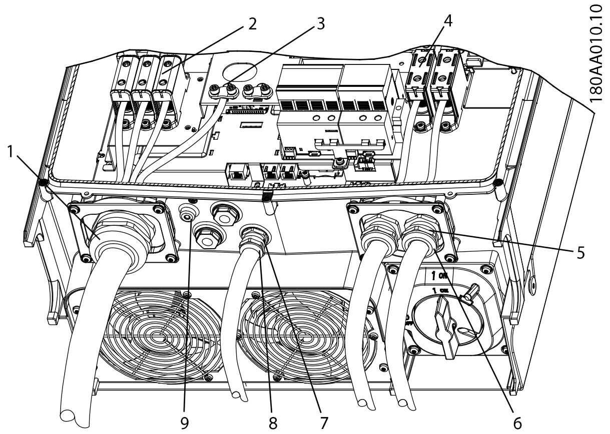


Illustration 3.12 Overview of Inverter with Torque Indications

	Parameter	Tool	Tightening Torque
1	M63 cable gland body	Wrench 65/68 mm	6 Nm (53 in-lbf)
2	Terminals on AC terminal block	TX 30	14 Nm (124 in-lbf)
3	PE	TX 30	3.9 Nm (35 in-lbf)
4	Terminal on DC	TX 30	14 Nm (124 in-lbf)
5	M32 cable gland body	Wrench 36 mm	6 Nm (53 in-lbf)
6	M32 cable gland compression nut	Wrench 36 mm	1.8 Nm (16 in-lbf)
7	M25 cable gland body	Wrench 27 mm	10 Nm (89 in-lbf)
8	M25 cable gland compression nut	Wrench 27 mm	1.8 Nm (16 in-lbf)
9	M6 equipment bonding	TX 20	3.9 Nm (35 in-lbf)
	Front screw (not shown)	TX 30	1.5 Nm (13 in-lbf)

Table 3.3 Torque Specifications

3.4 Cable Specifications

Terminal	Range	Max. conductor temperature rating	Conductor material	Cable jacket diameter
AC + PE	16-95 mm^2 6-4/0 AWG	90 °C	Al/Cu	37-44 mm
PV	16-95 mm^2 6-4/0 AWG	90 °C	Al/Cu	14-21 mm

Table 3.4 Acceptable Conductor Sizes

CAUTION

If the blind plugs are removed (see (7) in *Illustration 3.12*), use fittings with type rating: 3, 3S, 4, 4X, 6, 6P.

4 System Planning – Electrical

4.1 Introduction

The aim of this section is to provide general information for planning integration of the inverter into a PV system:

- PV system design, including earthing
- AC grid connection requirements; including choice of AC cable protection
- Ambient conditions, e.g. ventilation

4.2 DC Side

4.2.1 Requirements for PV Connection

The specifications for PV connection are shown in *Table 4.1*.

Parameter	MLX 60
MPP trackers/Inputs per MPPT	1/1 (external string combining)
Maximum input voltage, open circuit (V_{dcmax})	1000 V
Input voltage range	565–1000 V @ 400 Vac 680–1000 V @ 480 Vac
Rated voltage DC	630 V @ 400 Vac 710 V @ 480 Vac
MPPT voltage range - rated power	570–800 V @ 400 Vac 685–800 V @ 480 Vac
Max. MPPT current DC	110 A
Max. short circuit current DC	150 A

Table 4.1 PV Operating Conditions

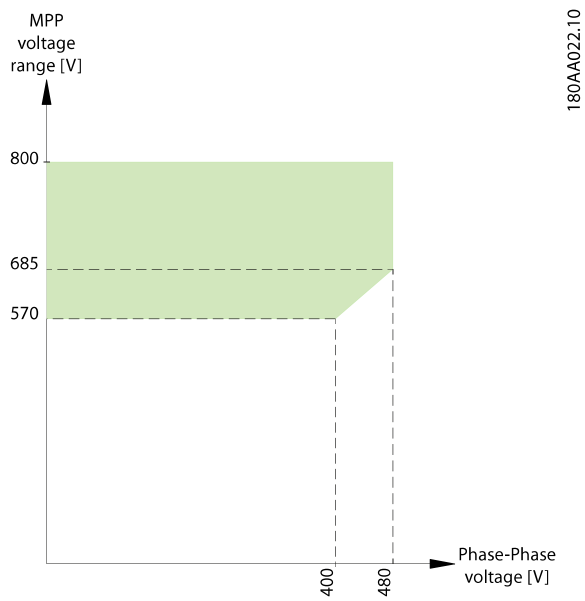


Illustration 4.1 Operating Range per MPP Tracker

To avoid damaging the inverter, observe the limits in *Table 4.1* when dimensioning the PV generator for the inverter.

⚠CAUTION

Always observe local requirements, rules, and regulations for the installation.

4.2.1.1 Maximum Open-circuit Voltage

The open-circuit voltage from the PV strings must not exceed the maximum open-circuit voltage limit of the inverter. Calculate the open-circuit voltage at the lowest PV module operating temperature expected for the location. If the module operating temperature is not well-defined, check local common practice. This calculation implies a maximum of 23–26 modules per string, for standard 60-cells c-Si modules. It depends on the local climate, module model, and installation conditions (for example ground based or flush mounted). Also check that the maximum system voltage of the PV modules is not exceeded.
Special requirements apply to thin-film modules. See *4.2.3 Thin Film*.

4.2.1.2 MPP Voltage

The string MPP voltage must be within the operational range of the inverter MPPT. Operational range is defined by:

- Minimum voltage operation MPP:
    - 570 V @ 400 V_{ac}
    - 685 V @ 480 V_{ac}
    - Other grid voltages: Estimate by '√2 x grid voltage [V_{ac}]'
- Maximum voltage operating MPP (800 V), for the temperature range of the PV modules

This requirement implies a minimum of 23–25 modules per string, for standard 60-cells c-Si modules. It depends on the location, module model, installation conditions, and grid voltage. If the input DC voltage is below the minimum MPP voltage for a period, the inverter will not trip but shift the operation up to the minimum voltage operation MPP, resulting in some yield losses.

MPP of the inverter can be below the minimum voltage operation MPP due to circumstances like:

- High cell temperature
- Partial shading conditions

- Insufficient number of modules per string
- High grid voltage

In general, the yield losses are minor for 400 V_{ac} grids. Yield losses can be minimised for 480 V_{ac} grids by:

- Increasing the number of modules per string
- Reducing the grid voltage seen by the inverters Grid voltage can be reduced by:
    - modifying the tap changer position in the transformer station
    - moving the inverters to another location
    - modifying the AC cable sections

If the previous actions are insufficient for a particular project to minimise the yield losses due to MPP range at a low level, an auto-transformer 480–400 V can be installed in order to reduce the grid voltage.

NOTICE

SMA can support you in the analysis of the yield losses due to MPP range for your particular project and in the selection of the best technical approach.

4.2.1.3 Short-circuit Current

The short-circuit current (Isc) must not exceed the absolute maximum that the inverter is able to withstand. Check the specification of the short-circuit current at the highest PV module operating temperature and the highest irradiance level expected. 125% of the module Isc at STC is used per string for the calculation, following the recommendations of the NEC and other regulations. This implies no more than 14 strings per inverter, for standard 60-cells c-Si modules.

4.2.1.4 MPP Current

The MLX inverter is able to provide full AC power even at its lower MPP range threshold. If the MPP current exceeds 110 A (due to high irradiance conditions or large number of strings per inverter), the inverter does not trip but shifts the operation point, resulting in some yield losses. In addition, the inverter limits the power intake by shifting the MPP when surplus PV power is available. For further information about PV over-sizing and related consequences, see *4.2.2 Determining Sizing Factor for PV Systems*.

4.2.1.5 PV to Earth Resistance

Monitoring of the PV to earth resistance is implemented for all grid codes. Supplying energy to the grid with too low resistance could be harmful to the inverter and/or the PV modules. PV modules designed according to the IEC61215 standard are only tested to a specific resistance of minimum 40 MΩ*m². Therefore, for an 84 kWp power plant with a 14% PV module efficiency, the total area of the modules yields 600 m². This yields a minimum resistance of 40 MΩ*m²/600 m² = 66.67 kΩ. The PV design must be within the required limit of the applied grid code. See *2.3.2 Functional Safety* and *2.5 Grid Code*.

4.2.1.6 Earthing

It is not possible to earth any of the terminals of the PV arrays. However, it can be compulsory to earth all conductive materials, for example, the mounting system, to comply with the general codes for electrical installations. In addition, the PE terminal of the inverter must be always connected to earth.

⚠CAUTION

It can be harmful to humans if not properly grounded.

4.2.1.7 Parallel Connection of PV Arrays

The MLX inverter has 1 input and 1 MPPT. An external string combiner is always required. Due to the number of strings in parallel, fusing of the strings in the string combiner is required. The recommendation is to place the string combiner close to the strings. The use of only 1 cable for each pole from the PV array to the inverter reduces the cable and installation costs.

4.2.1.8 PV Cable Dimensions and Layout

DC cabling is composed of 2 different cable segments:

- The string cabling from the modules to the string combiner (usually 4 mm² or 6 mm²)
- The combined line from the string combiner to the inverter (recommended at least 50 mm² (copper) or 70 mm² (aluminium))

The cable section must be selected for each segment according to the current capacity of the cable and maximum DC cable losses according to local legislation.

Current capacity of the cable depends on the material of the wires (copper or aluminium) and the type of insulation (for example PVC or XLPE). Factors as for example high ambient temperature or grouping of cables produce derating of the current capacity of the cable. Follow the local legislation for correction factors calculation.

The maximum DC cable losses permitted also depend on the local legislation. Note that the limit must include both the losses in the strings and the combined line. Cable losses depend on the material of the wires (copper or aluminium), cross-section area and the cable length.

Take the following into account:

- The total length for a string is defined as twice the physical distance between the string and the string combiner plus the length of the PV cables included in the modules

- The total length for the combined line is defined as twice the physical distance between the string combiner and the inverter

NOTICE

For the combined line, the maximum cable section connectable to the inverter (95 mm^2 / AWG 4/0) must be addressed in the system design. If the calculated cable section exceeds this limit, change the cable type, the sub-plant size, or the location of the string combiners/ inverters.

Avoid looping the DC cables as they can act as an antenna of radio-noise emitted by the inverter. Cables with positive and negative polarity must be placed side by side with as little space between them as possible. This also lowers the induced voltage in case of lightning and reduces the risk of damage.

4.2.2 Determining Sizing Factor for PV Systems

When determining the PV system size factor, a specific analysis is preferred, especially for large PV installations. Local rules of thumb for choosing the sizing factor can be determined, depending on local conditions, for example:

- Local climate
- Local legislation
- System price level

To select the optimal configuration/sizing factor, an investment analysis must be made. Large sizing factors usually reduce specific investment costs (€/kWp) but could have lower specific yield (kWh/kWp) due to derating losses in the inverter (excessive DC power or overheating) and so, lower income. Small sizing factors result in greater investment costs. However, specific yield is potentially greater due to little or no derating loss.

Installations in regions with frequent irradiation levels over 1,000 W/m^2 have lower levels of sizing factor than installations in regions with infrequent irradiance levels over 1000 W/m^2. In particular, if high ambient temperatures are not expected during the irradiance peaks.

A lower sizing factor must also be considered for tracking systems, because they allow more frequent high irradiance levels. In addition, derating due to overheating of the inverter must be considered for tracking systems in hot climates. This can also reduce the recommended sizing factor further.

The MLX inverter supports different sizing factors, depending on the number of modules per string and number of strings per inverter.
Any configuration that observes the varying conditions for different applications: the limits in *Table 4.1* for short-circuit current and open-circuit voltage will be considered as valid and so covered by warranty.

4.2.3 Thin Film

The MLX inverter is a transformerless inverter without booster and so the PV voltage is distributed symmetrically to earth. Grounding of the minus pole is not allowed.

- The use of transformerless inverters as MLX is approved by many thin-film module manufacturers not requiring grounding of the minus pole
- The MLX inverter is not compatible with thin-film modules with a requirement of minus pole grounding

NOTICE

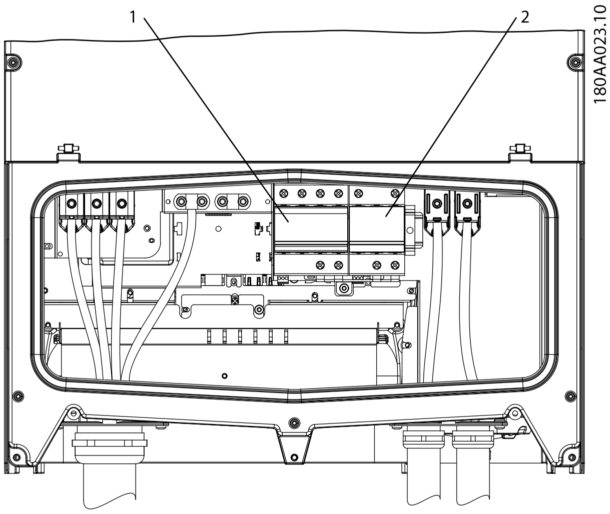
It is important to get approval from the module manufacturer before installing thin-film modules with MLX inverters.

CAUTION

Module voltage during initial degradation can be higher than the rated voltage in the data sheet. This must be considered when designing the PV system, since excessive DC voltage can damage the inverter. Module current can also lie above the inverter current limit during the initial degradation. In this case, the inverter decreases the output power accordingly, resulting in lower yield. Therefore, when designing, take inverter and module specifications both before and after initial degradation into consideration.

4.2.4 Internal Surge Overvoltage Protection

The MLX inverter includes high performance DIN-rail SPDs in both AC (type II+III, according to IEC 61643-11) and DC (type II) sides. The SPDs are easy to replace if damaged.



1	SPD (AC) with 3 fuses. Fuse to far right (green) does not require any replacement.
2	SPD (DC) with 2 fuses. Fuse in the middle (green) does not require any replacement.

Illustration 4.2 Overview of Installation Area

Based in the combination of gas-filled spark gap and MOVs technologies, SPDs in MLX have the following advantages:

- No leakage or operation current: no insulation faults and tripping of the inverter, and no aging
- No follow current: no tripping of the upstream overcurrent protection during surge events

If the PV system is installed on a building with an existing lightning protection system, the PV system must also be properly included in the lightning protection system.

CAUTION

When mounting the inverter on a grounded metallic surface, ensure that the inverter's earthing point and mounting plate are directly connected. Failure to do so can potentially result in material damage to the inverter, via arcing between the mounting plate and the inverter enclosure.

4.2.5 Thermal Management

All power electronics generate excess heat, which must be controlled and removed to avoid damage and to achieve high reliability and long life. The temperature around critical components like the integrated power modules is continuously measured to protect the electronics against overheating. If the temperature exceeds the limits, the inverter reduces output power to maintain temperature at a safe level.

The thermal management concept of the inverter is based on forced cooling with speed-controlled fans. The fans are electronically controlled and are only active when needed. The rear of the inverter is designed as a heat sink that removes the heat generated by the power semiconductors in the integrated power modules. Additionally, the magnetic parts are ventilated by force. At high altitudes, the cooling capacity of the air is reduced. The fan control attempts to compensate for this reduced cooling. At altitudes greater than 1000 m, consider derating of the inverter power when planning system layout, to avoid loss of energy.

Altitude	**2000 m**
Max. load of inverter	95%

Table 4.2 Compensation for Altitude

NOTICE

PELV protection is effective up to 2000 m above sea level only.

Account for other altitude-related factors, such as increased irradiation.

Optimise reliability and lifetime by mounting the inverter in a location with low ambient temperature.

NOTICE

For indoor locations, consider a maximum airflow of 640 m^3/h and a maximum heat dissipation of 1500 W per inverter.

4.2.6 Simulation of PV

Contact the supplier before connecting the inverter to a power supply for testing purposes, for example, simulation of PV. The inverter has built-in functionalities that can harm the power supply or the inverter.

4.2.7 PV Field Capacitance

PV fields have a small parasitic capacitance, which is directly proportional to the area and inversely proportional to the thickness of the modules. Depending on the weather conditions, a total capacity of about 50–150 nF/kW can be determined for a plant with crystalline modules. For standard thin-film modules (CdTe, CIS, and a-Si) similar values are expected. Under extreme conditions, stainless steel sheet-based thin-film modules can produce values near to 1 mF/kW.

The MLX inverter is designed to operate with a PV field capacitance up to 8.8 µF. If this limit is exceeded, the capacitive leakage current can provoke undesired tripping of the RCMU class B of the MLX inverter, and, as a result, the disconnection of the inverter from the grid.

WARNING

Plants with no grounding of the structure can be dangerous. If a grounded person touches the modules, a capacitive leakage current can flow through his body. It is especially important to ground the support structure of the modules when transformerless inverter having AC ripple on the DC side are installed in combination with high-capacity PV modules. This draws the capacitive leakage current to ground and prevents any bodily harm.

Observe the National Electric Code, ANSI/NFPA 70.
Input and output circuits are isolated from the enclosure. System grounding is the responsibility of the installer.

4.3 AC Side

4.3.1 Requirements for AC Connection

CAUTION

Always follow local regulations.

The MLX inverters are designed with a 3-phased and protective earth (without neutral) AC grid interface for operation under the conditions described in *Table 4.3*.

Parameter	Operation range
Grid interface	3P + PE (delta or WYE)
Grid voltage, phase-phase	400 V or 480 V (+/- 10%)
Grid frequency	50 Hz or 60 Hz (+/- 10%)

Table 4.3 AC Operating Conditions

When choosing grid code, the parameters in the above specification are limited to comply with the specific grid codes.

Earthing systems
The MLX inverters can operate on TN-S, TN-C, TN-C-S, and TT systems. Ungrounded delta systems are supported, but IT systems are not.

Where an external RCD is required in addition to the built-in RCMU, a type B RCD must be used. Consider a current sensitivity of 600 mA per inverter to avoid nuisance tripping. *Table 4.4* shows the maximum values of the earth resistance in TT grids, depending on the sensitivity of the RCD to have lower values than 50 V of contact voltage, and so a proper protection.

Current sensitivity		Maximum value of earth resistance
Basic sensitivity	20 A	2.5 Ω
	10 A	5 Ω
	5 A	10 Ω
	3 A	17 Ω
Medium sensitivity	1 A	50 Ω
	500 mA	100 Ω
	300 mA	167 Ω
	100 mA	500 Ω
High sensitivity	≤ 30 mA	> 500 Ω

Table 4.4 Maximum Earth Resistance in TT Grids, Depending on the Current Sensitivity of the RCD

NOTICE

When using TN-C earthing to avoid earth currents in the communication cable, ensure identical earthing potential of all inverters.

4.3.2 AC Connection Protection

No consumer load can be applied between the mains circuit breaker/fuses and the inverters. An overload of the cable might not be recognised. Always use separate lines for consumer loads, protected against overcurrent and short circuit with proper fuses/circuit breakers.

Use circuit breakers/fuses with switch functionality for short-circuit protection and safe disconnection of the inverters. Threaded fuse elements like 'Diazed' (D-type) are not considered adequate as a switch. Fuse holder can be damaged if dismounted under load. 'Neozed' (D03-type, 100 A) can be installed in fuse-switch disconnection units adequate for switch purposes. NH fuses require an additional tool, a grip handle.

Dedicated circuit breakers/fuses for each individual inverter output line must be installed according to the specifications in *Table 6.4*, in which it has been taken into account that derating of the circuit breakers/fuses can be necessary due to self-heating when installed in groups, or if exposed to heat. The maximum fuse size is 125 A.

For TN grids with no RCDs installed, check that the rating and curve of the circuit breakers/fuses selected are adequate for a proper residual current protection (tripping fast enough), considering the type of cable and cable length.

Consider the maximum short-circuit current in the location of the circuit breaker/fuses. Short-circuit currents can be as high as 60 kA, if the short-circuit current is produced inside a 2.5 MVA transformer station. This is the reason why only NH fuses or MCCBs, with higher breaking capacity, should be used in the main LV protection board integrated in the transformer station, and D0 fuses and MCBs, with lower breaking capacity, should only be used for AC combiners distributed in the plant.

AC combiners are not specifically required for AC distribution in ground-based plants with MLX inverters: the output line of each inverter can be directly protected with NH fuses in a main LV protection board integrated in the transformer station. If AC layout includes AC combiners and a main LV protection board, selective coordination of protection should be considered, in order to avoid tripping of protection in the main LV protection board in case of short circuit in an inverter line. This selective coordination can be particularly complicated when MCBs are used in the AC combiner and MCCBs in the main LV protection board.

Use the PV load switch to turn off the inverter before removing/replacing the fuse elements.
For information about cable requirements, see *3.4 Cable Specifications*.

4.3.3 Grid Impedance

The grid impedance must correspond to the power size of the application* in order to avoid unintended disconnection from the grid or derating of the output power. Ensure that cable dimensions are correct, to avoid losses. Additionally the no load voltage at the connection point must be taken into account.

**The total system impedance is defined in per cent as:*
Ztotal = ZPCC + ZtrafoMVHV + ZtrafoLVMV [%], where:

- *ZPCC is the per cent short-circuit impedance of the point of common coupling (PCC) calculated based on the short-circuit power available at the PCC (this data is typically provided by the DNO/TSO),*
- *ZtrafoMVHV is the short-circuit impedance of the MV/HV transformer unit as stated in the transformer datasheet (if non-existent then use 0),*
- *ZtrafoLVMV is the short-circuit impedance of the LV/MV transformer unit as stated in the transformer datasheet (if non-existent then use a default 6%).*

For MLX 60 kVA inverter, the maximum total system impedance Ztotal value is 30%.

4.3.4 AC Cable Considerations

The cable cross-section must be selected according to the current capacity of the cable and the maximum AC cable losses according to local legislation. In TN grids, if no RCDs are installed, cable cross-section in combination with the short-circuit protection installed, should also ensure a proper residual current protection.

Current capacity of the cable depends on the wire material (copper or aluminium) and insulation type (for example PVC or XLPE). Factors, such as high ambient temperature or grouping of cables, produce derating of the current capacity of the cable. Follow the local legislation for correction factors calculation.

The maximum AC cable losses permitted also depend on the local legislation. Cable losses depend on the wire material (copper or aluminium), the cable cross-section and the cable length.

In TN grids, due to the low impedance path for the fault loop, fault currents are high. This means that the short-circuit protection can also be used for residual current protection, if a tripping time lower than 0.4 s can be ensured, according to IEC 60364-4-41, table 41.1. This can be checked using the time/current curves of the fuses/circuit breakers installed for the minimum short-circuit current ($I_{sc,min}$) expected in the line they protect.

Initially consider a minimum AC cabling section of 35 mm^2 (Cu) and 50 mm^2 (Al).

NOTICE

The maximum cable cross-section connectable to the inverter (95 mm^2 / AWG 4/0) must be addressed in the system design. If the calculated cable cross-section exceeds this limit, either use AC combiners, change the cable type, the subplant size or the location of the inverters.

5 Communication and System Planning, Inverter Manager

5.1 Ethernet Communication

5.1.1 System Overview

The system consists of 4 components:

- PC with LCS software
- Router/DHCP for plant network
- Inverter Manager
- MLX inverters

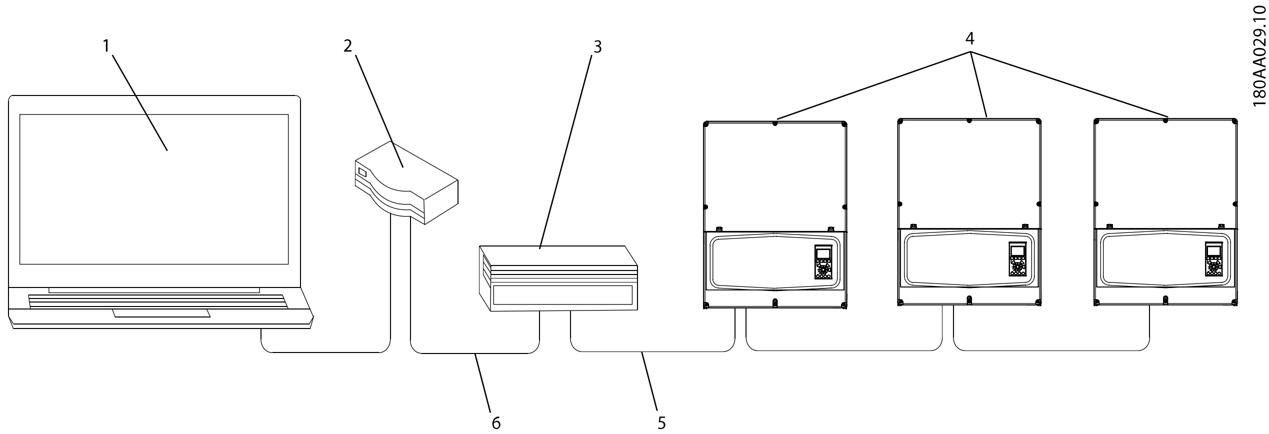


Illustration 5.1 Commissioning of Inverters Using LCS Tool

1	LCS Tool
2	Router/DHCP
3	MLX Inverter Manager
4	MLX inverter
5	LAN 2
6	LAN 1

This section describes how the system works and the function of the individual components.

The system is divided into 2 Ethernet networks; Plant network and inverter network (see *Illustration 5.1*). The plant network is the communication interface to the plant and can operate together with other IT equipment, while the inverter network must only be used for MLX series inverters.

The plant network must have a router/DHCP server as the Inverter Manager requires automatic IP assignment. It is recommended to use professional grade routers and switches.

NOTICE

When designing the plant network it is important to consider network security in order to ensure that only authorised personnel can access the plant network. This is especially important when the plant network is connected to the internet.

⚠WARNING

SMA accepts no liability for damage or losses due to unauthorised access to the plant.

The inverters are equipped with a 2 port Ethernet switch allowing for daisy chaining. The Inverter Manager hosts the DHCP server for the up to 42 inverters that can be connected per Inverter Manager. In order to commission the plant, all inverters must be connected to the Inverter Manager. If the inverters loose connection they will disconnect from the grid. Plants requiring more than 42 inverters can use multiple Inverter Managers in the plant network.

5.1.2 Inverter Manager

The Inverter Manager separates the plant network and the inverter network and handles the following plant level tasks:

- Allows access through SunSpec Modbus TCP profile (acts as gateway to the inverters)
- Distributed control of active and reactive power (for example through reactive setpoint curves and Power Level Adjustment)
- Portal upload to FTP server
- Access to plant configuration and service through LCS

- Connection interfaces for external devices such as I/O box (grid management) and weather stations

5.2 User Interfaces

The Local Commissioning and Service tool (LCS) is used to commission the Inverter Manager and inverters, enabling them to start injecting power into the grid. With the LCS Tool it is possible to:

- Perform software update of the system
- Read out inverter values (voltage, current, etc.)
- Display inverter event logs
- Load custom grid code file (information about how to obtain custom grid file see *2.5 Grid Code*)
- Configure portal FTP upload
- Access commissioning reports
- Modbus gateway address list
- Add/replace inverters

The MLX inverters and Inverter Managers must be commissioned via the Local Commissioning and Service Tool (LCS Tool). Commissioning is required before the MLX inverters can connect to the AC grid and inject power.

The LCS Tool is available from the download area at *www.sma.de*.

The hardware requirements for the LCS Tool are:

- PC running Windows^{TM} 7 and later
- 1 GB HDD
- 2 GB RAM

The LCS Tool must be installed on a local PC drive. The PC must be connected to the plant network of the Inverter Manager.

NOTICE

The Inverter Manager must have an IP address assigned by a DHCP server on the LAN 1 port.
It is important that the PC running the LCS Tool is connected to the same IP subnet as the Inverter Manager.
Port LAN 2 is intended for MLX inverters exclusively.

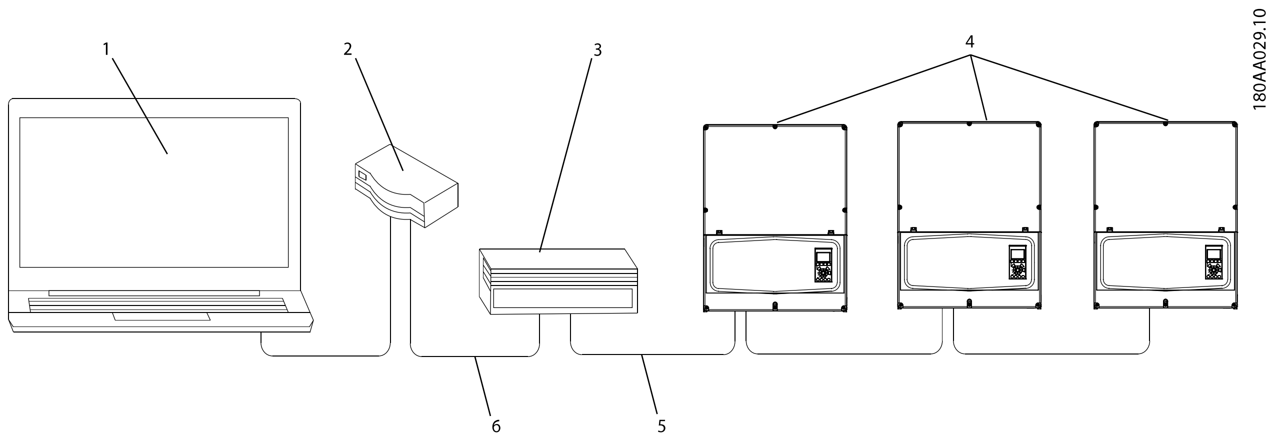


Illustration 5.2 Commissioning of Inverters Using LCS Tool

1	LCS Tool
2	Router/DHCP
3	MLX Inverter Manager
4	MLX inverter
5	LAN 2 (inverter network)
6	LAN 1 (plant network)

5.3 I/O Box

The I/O box is used for transmitting the relay state from a ripple control receiver, provided by the DNO, to the Inverter Manager over RS-485. An I/O box is required for each Inverter Manager.

5.4 Weather Station

Any SunSpec-compliant RS-485 weather station can be connected to the Inverter Manager.

6 Technical Data

6.1 Technical Data

Parameter	MLX 60
AC	
Rated apparent power[1)]	60 kVA
Rated active power[2)]	60 kW
Reactive power range[1)]	0–60 kVAr
Rated grid voltage (voltage range)	3P + PE (delta or WYE) / 400-480 V (+/- 10%)
Grounding schemes supported	TT, TN
Rated current AC	3 x 87 A
Max. current AC	3 x 87 A
AC current distortion (THD at nominal output power)	< 1%
Power factor default	> 0.99 at rated power
Power factor - regulated	0.8 over-excited, 0.8 under-excited
Stand-by power consumption (comm. only)	3 W
Rated grid frequency (frequency range)	50/60 Hz (+/- 10%)
DC	
Input voltage range	565–1000 V @ 400 V_{ac} 680–1000 V @ 480 V_{ac}
Rated voltage DC	630 V @ 400 V_{ac} 710 V @ 480 V_{ac}
MPPT voltage range - rated power	570–800 V @ 400 V_{ac} 685–800 V @ 480 V_{ac}
Max. voltage DC	1000 V
Min. on grid power	100 W
Max. MPPT current DC[4)]	110 A
Max. short-circuit current DC[4)]	150 A
MPP tracker/Input per MPPT	1 / 1 (external string combining)
Efficiency	
Max. efficiency EU/CEC	98.8%
EU efficiency at 570 V_{dc}	98.5%
CEC efficiency at 400/480 V_{ac}	98.0% / 98.5%
MPPT efficiency static	99.9%
Enclosure	
Dimensions (H x W x D)	740 × 570 × 300 mm (29 × 22.5 × 12 in)
Weight	75 kg (165 lbs)[3)]
Acoustic noise level	55 dB(A) (preliminary value)

Table 6.1 Specifications

[1)] *At rated grid voltage.*

[2)] *At rated grid voltage, Cos(phi)=1.*

[3)] *Depending on installed options.*

[4)] *Under any conditions.*

Parameter		MLX series
Electrical		
	Electrical Safety	• IEC 62109-1/IEC 62109-2 (Class I, grounded – communication part Class II, PELV) • UL 1741 with non-Isolated EPS Interactive PV Inverters • IEEE 1547
	PELV on the communication and control card	Class II
Functional		
	Functional Safety	• Voltage and frequency surveillance • DC content of AC current surveillance • Insulation resistance surveillance • Residual current monitoring • UL1998
	Islanding detection - loss of mains	• Active frequency shift • Disconnection • 3-phase monitoring • ROCOF/SFS
	RCD compatibility[1)]	Type B, 600 mA

Table 6.2 Safety Specifications

[1)] *Depending on local regulations.*

6.2 Derating Limits

To ensure that the inverters can produce the rated power, measurement inaccuracies are taken into account when enforcing the derating limits stated in *2.4.2 Inverter Derating*.

(Limit = rated value + tolerance).

6.3 Norms and Standards

International standards	MLX series
Efficiency	EU efficiency, Standard: EN50530
	CEC efficiency, Standard: CEC guideline Test procedure: Performance Test Protocol for Evaluating Inverters Used in Grid-Connected Photovoltaic Systems (Draft): March 1, 2005
Directive LVD	2006/95/EC
Directive EMC	2004/108/EC
Safety	IEC 62109-1/IEC 62109-2
	UL 1741
	UL 508i
Functional safety	IEC 62109-2
	UL 1741/IEEE 1547
EMC, immunity	EN 61000-6-1
	EN 61000-6-2
EMC, emission	EN 61000-6-3
	EN 61000-6-4
	CISPR 11 Class B
	FCC Part 15
Utility interference	EN 61000-3-12
CE	Yes

International standards	MLX series
Utility characteristics	IEC 61727
	EN 50160
	IEEE 1547 UI

Table 6.3 International Standards Compliance

Approvals and certificates are available from the download area at *www.sma.de*.

6.4 Mains Circuit Specifications

Parameter	Specification
Maximum inverter current, I_{acmax}	87 A
Recommended blow fuse type gL/gG (IEC 60269-1)	100-125 A
Recommended blow fuse Class T (UL/USA)	125 A
Recommended MCB type B or C	125 A
Maximum fuse size	125 A

Table 6.4 Mains Circuit Specifications

NOTICE

Observe local regulations.

6

6.5 Auxiliary Interface Specifications

Interface	Parameter	Parameter Details	Specification
Ethernet	Cable	Cable jacket diameter (⌀)	2 x 5-7 mm
		Cable type	Shielded Twisted Pair (STP CAT 5e or SFTP CAT 5e)[1)]
		Cable characteristic impedance	100 Ω – 120 Ω
	RJ-45 connectors: 2 pcs RJ-45 for Ethernet	Wire gauge	24-26 AWG (depending on mating metallic RJ-45 plug)
		Cable shield termination	Via metallic RJ-45 plug
	Galvanic interface insulation		Yes, 500 Vrms
	Direct contact protection	Double/Reinforced insulation	Yes
	Short-circuit protection		Yes
	Communication	Network topology	Star and daisy chain
	Cable	Max. cable length between inverters	100 m (328 ft)
	Max. number of inverters	Per Inverter Manager	42

Table 6.5 Auxiliary Interface Specifications

1) For outdoor and/or burial use, ensure that the appropriate type of Ethernet cable is used.

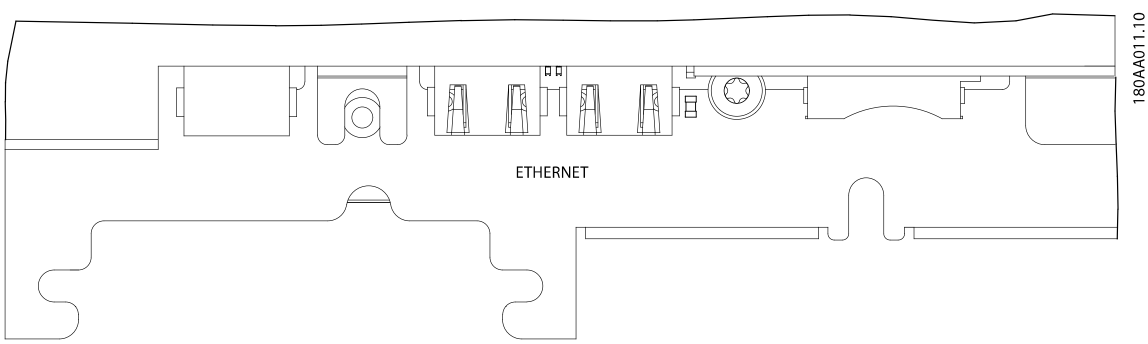


Illustration 6.1 Auxiliary Interfaces (Cutout of Inverter Installation Compartment)

6.6 Ethernet Connections

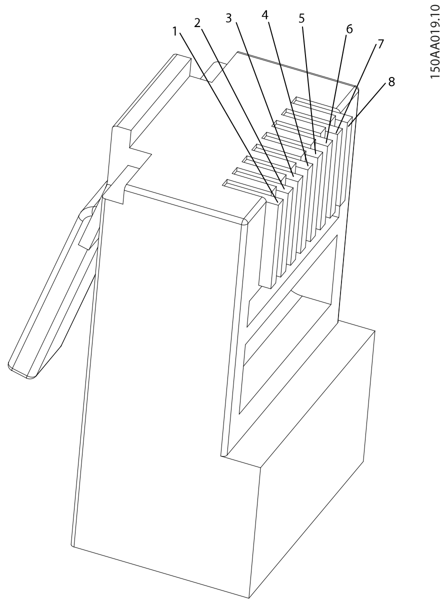


Illustration 6.2 RJ-45 Pinout Detail for Ethernet

Pinout Ethernet	Colour Standard Cat 5 T-568A	Cat 5 T-568B
1. RX+	Green/white	Orange/white
2. RX	Green	Orange
3. TX+	Orange/white	Green/white
4.	Blue	Blue
5.	Blue/white	Blue/white
6. TX-	Orange	Green
7.	Brown/white	Brown/white
8.	Brown	Brown

Table 6.6 RJ-45 Pinout Detail for Ethernet

6.6.1 Network Topology

The inverter has 2 Ethernet RJ-45 connectors enabling the connection of several inverters in a line topology as an alternative to the typical star topology.

NOTICE

Ring topology (C in *Illustration 6.3*) is only permitted if realised with Ethernet switch supporting spanning tree.

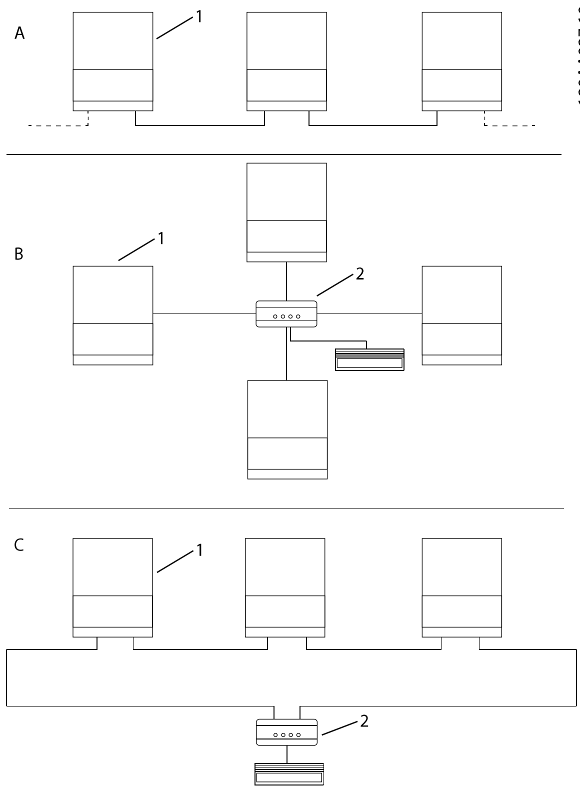


Illustration 6.3 Network Topology

A	Linear daisy chain
B	Star topology
C	Ring topology (only if spanning tree is used)
1	MLX inverter
2	Ethernet switch

Table 6.7 Network Topology

Status of the LEDs next to the Ethernet port is explained in *Table 6.8*. There are 2 LEDs per port.

Status	Yellow LED	Green LED
Off	Link speed 10 Mbit	No link
On	Link speed 100 Mbit	Link
Flashing	-	Activity

Table 6.8 LED Status

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