Conext CL125 Inverter

Solution Guide for Decentralized PV Systems (IEC Version)

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PVSCL125E

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About This Guide

Purpose

The purpose of this Solution Guide is to provide explanations for designing a decentralized PV system using Conext CL125E String Inverters and Balance of System (BOS) components offered by Schneider Electric. It describes the interfaces required to implement this architecture and gives rules to design the solution.

Scope

This Guide provides technical information and balance of system design recommendations. It explains the design requirements of each of the system components and provides details on how to choose the correct recommendations.

The information provided in this guide does not modify, replace, or waive any instruction or recommendations described in the product Installation and Owner's Guides including warranties of Schneider Electric products. Always consult the Installation and Owner's guides of a Schneider Electric product when installing and using that product in a decentralized PV system design using Conext CL inverters.

For help in designing a PV power plant contact your Schneider Electric Sales Representative or visit the Schneider Electric website for more information at solar.schneider-electric.com.

Audience

The Guide is intended for system integrators or engineers who plan to design a De-centralize PV system using Schneider Electric Conext CL125 Inverters and other Schneider Electric equipment.

The information in this Solution Guide is intended for qualified personnel. Qualified personnel have training, knowledge, and experience in:

- Analyzing application needs and designing PV Decentralize Systems with transformer-less string inverters.
- Installing electrical equipment and PV power systems (up to 1500 V).
- Applying all applicable local and international installation codes.
- Analyzing and reducing the hazards involved in performing electrical work.
- Selecting and using Personal Protective Equipment (PPE).

Organization

This Guide is organized into seven chapters.

Chapter 1, Introduction

Chapter 2, Decentralized PV Solutions

Chapter 3, DC System Design

Chapter 4, AC System Design

Chapter 5, Important Aspects of a Decentralized System Design

Chapter 6, Layout Optimization

Chapter 7, Frequently Asked Questions (FAQ)

Related Information

You can find more information about Schneider Electric as well as its products and services at solar.schneider-electric.com.

Important Safety Instructions

READ AND SAVE THESE INSTRUCTIONS - DO NOT DISCARD

This document contains important safety instructions that must be followed during installation procedures (if applicable). **Read and keep this Solution Guide for future reference.**

Read these instructions carefully and look at the equipment (if applicable) to become familiar with the device before trying to install, operate, service or maintain it. The following special messages may appear throughout this bulletin or on the equipment to warn of potential hazards or to call attention to information that clarifies or simplifies a procedure.

The addition of either symbol to a “Danger” or “Warning” safety label indicates that an electrical hazard exists which will result in personal injury if the instructions are not followed.

This is the safety alert symbol. It is used to alert you to potential personal injury hazards. Obey all safety messages that follow this symbol to avoid possible injury or death.

⚠ DANGER
DANGER indicates an imminently hazardous situation, which, if not avoided, will result in death or serious injury.

⚠ WARNING
WARNING indicates a potentially hazardous situation, which, if not avoided, can result in death or serious injury.

⚠ CAUTION
CAUTION indicates a potentially hazardous situation, which, if not avoided, can result in moderate or minor injury.

NOTICE
NOTICE indicates important information that you need to read carefully.

⚠ DANGER

RISK OF FIRE, ELECTRIC SHOCK, EXPLOSION, AND ARC FLASH

This Solution Guide is in addition to, and incorporates by reference, the relevant product manuals for the Conext CL125 Inverter. Before reviewing this Solution Guide you must read the relevant product manuals. Unless specified, information on safety, specifications, installation, and operation is as shown in the primary documentation received with the products. Ensure you are familiar with that information before proceeding.

Failure to follow these instructions will result in death or serious injury.

⚠ DANGER

ELECTRICAL SHOCK AND FIRE HAZARD

Installation including wiring must be done by qualified personnel to ensure compliance with all applicable installation and electrical codes including relevant local, regional, and national regulations. Installation instructions are not covered in this Solution Guide but are included in the relevant product manuals for the Conext CL125 Inverter. Those instructions are provided for use by qualified installers only.

Failure to follow these instructions will result in death or serious injury.

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1 Introduction

This introduction chapter contains information:

- About the Conext CL125 Inverter
- Decentralized Photovoltaic (PV) Architecture
- Key Specifications of the Conext CL Inverter
- Key Features of Integrated Wiring Box

Decentralized Photovoltaic (PV) Architecture

Use of a decentralized PV Architecture

Fundamentally, De-Centralized PV systems are designed by locating small power inverters in a decentralized manner on the PV field area in the vicinity of PV modules to allow for connection of the strings as simply as possible.

Advantages of a decentralized PV architecture include:

- Easy adaptation of the solution to roof or plant specificities
- Easy installation of the inverters on roof or plant
- Easy electrical protection
- Easy connection to the grid
- Easy monitoring
- Easy system maintenance
- Greater energy production

Use of a Three Phase String Conext CL125 Inverter

The new Conext CL125E (IEC) grid-tie three phase string inverters are designed for outdoor installation and are the ideal solution for decentralized power plants in multiple megawatt (MW) ranges. With high-power density, market-leading power conversion efficiency and wide input range Maximum Power Point Trackers (MPPTs), these inverters are ideally suited for large scale PV plants.

⚠ WARNING

ELECTRICAL SHOCK HAZARD

- The Conext CL125 Inverters are 3-phase, grid tie transformer-less inverters, designed for floating (ungrounded) PV modules.
- Always refer to national and local installation and electrical codes when designing a power system.

Failure to follow these instruction can result in death or serious injury.

About the Conext CL125 Inverter

Figure 1-1 Conext CL125 Inverter

The Conext CL Inverter is a three-phase, transformer-less, string inverter designed for high efficiency, easy installation, and maximum yield.

The inverter is designed to collect maximum available energy from the PV array by constantly adjusting its output power to track the maximum power point (MPP) of the PV array. The CL Inverter has a single MPPT channel as it is designed to be used in large scale PV plants with uniform strings.

The CL Inverter's DC input side accommodates PV arrays with open circuit voltages of up to 1500 VDC. It has a single pair of PV input terminals with direct connection from an external PV combiner box. The terminals can accept cables with a maximum size of 200 mm^2.

The CL Inverter has a single stage transformer-less design. Therefore, it has no galvanic isolation. It is light-weight, efficient, and has high power density suitable for large scale PV plants.

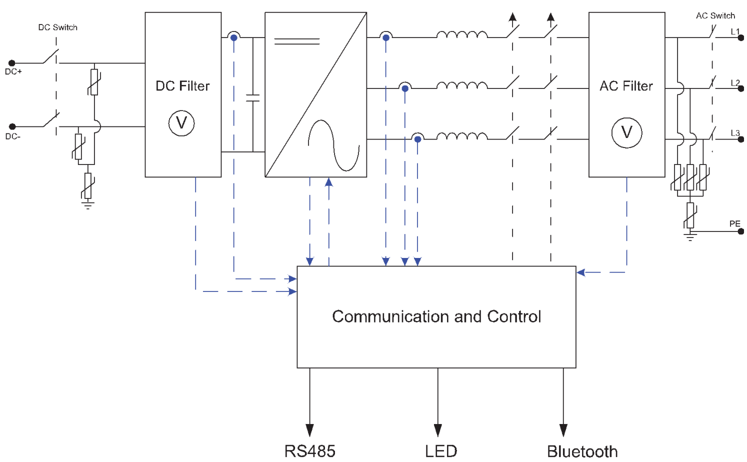

Figure 1-2 Typical PV grid-tied installation using Conext CL inverters

Key Specifications of the Conext CL Inverter

- Conext CL125E inverter: 125 kVA, 125kW (1500 VDC systems)
- PV compatibility: Designed to work with 1500V floating PV systems
- 600V, Three-phase STAR or DELTA type AC wiring output(3P+PE)
- Operating voltage – 860V-1450V
- Full Power MPPT voltage – 860V-1250V
- Supports high DC/AC over-paneling ratio (up to 1.5)
- Energy harvest (MPPT) efficiency: >99% (static-99.5% & Dynamic-99%)
- CEC efficiency 98.5%
- Maximum power conversion efficiency: ~98.8%
- Power factor adjustment range: 0.8 capacitive to 0.8 inductive
- Low AC output current distortion (THD < 3%) @ nominal power
- IP65 (electronics) and IP20 (rear portion) protection class for installation in outdoor environments
- -25 to 60 °C Operating temperature range
- RS485-Modbus and Modbus TCP - Loop-in Loop-out
- eConfigure CL125 APP and Conext CL EasyConfig tool for local firmware upgrade and configuration

Key Features of Integrated Wiring Box

- Integrated AC switch
- Integrated DC switch.
- AC Terminals with 3Phase +PE
- AC terminals with screw type (Max. 185 mm^2, cu or AL)
- DC terminals with screw type (Max. 200 mm^2, cu or AL)
- Type 2 AC (PCB mounted) and Type 2 DC (Modular) Surge Protection (SPD)

2 Decentralized PV Solutions

This chapter on decentralized PV solutions contains the following information.

- Drivers for decentralizing system design
- Easy configuration and firmware upgrade tool such as the eConfigure CL125 APP
- PV System Modeling
- PV System Design Using Conext CL125 Inverters
- Building Blocks of a Decentralized PV System
- Inverter location

Why Decentralize PV Solutions?

Drivers for decentralizing system design

1. Lower cost of installation and easy to install
   - Smaller units have lighter weight and are easier to handle
   - Inverters can be mounted directly on/underneath the photovoltaic (PV) mounting structures
   - Product is easy and inexpensive to ship and can be installed without heavy and expensive cranes
   - No concrete mounting pad required: unit is mounted directly to wall, pole or PV module racking
2. Easy to service and increased energy harvest
   - If the inverter detects a failure event, only part of the field is affected versus a large portion of the field when a large central inverter is used, which means minimal down-time and greater return on investment (ROI)
   - High efficiency for greater harvest
3. Easy electrical protection
   - DC circuit length reduces up to the racks with short runs up to the inverters next to the PV panel strings
   - Lower DC cable losses
   - AC circuit is enlarged, requiring additional AC equipment which is typically less expensive and more readily available
4. Easy adaptation to PV plant layout
   - De-centralized approach covers more area of the plant
   - Tracker or Fixt mounts – smaller PV inverters bring more flexibility
5. Easy connection to the grid
   - CL125E offers connectivity to both STAR and **DELTA** type windings
   - Multiple Inverters (up to 20) could be paralleled to a single transformer
6. Easy monitoring and configuration
   - Modbus RS485 and Modbus TCP daisy chain capability
   - Monitoring ready with major third-party service providers
   - Easy configuration and firmware upgrade tool such as the eConfigure CL125 APP

PV System Modeling

Important aspects to consider for PV system modeling are:

- Site
- Type of system
- Losses

Site

It is important to interpret site conditions carefully and model the exact conditions in the PV system design software. These conditions include shadow from surroundings, ground slope, layout boundary conditions, rain water catchment area, PV module string arrangements, shape of the layout, obstacles such as power lines, gas pipelines, rivers, archaeological conditions, and so on.

Once all possible factors affecting the PV system design are listed and assessed, the capacity of the selected PV installation site can be determined for further processing. Government agency permits and statutory clearances also depend on these factors. Cost of the land and the overall PV system varies with respect to these conditions.

System

PV system installation can be grid tied, stand alone, or hybrid. It could be ground-mounted with tracking option.

Quantum and usage of generated electricity is an important factor when deciding on the type of system. A good system design has high efficiency, flexibility and a modular approach for faster and quicker installations. When designing large-scale PV power plants, the most attention should be spent on the response of the PV plant power output against dynamic conditions of the grid. Faster power curtailment or fault ride through capability of Inverter is useful for this purpose.

Selection of major components like PV modules, inverters and mounting structures comprises the majority of system modelling and design. These three components also affect the cost, output, and efficiency of the system.

Losses

Any PV system has two major types of losses. Losses associated with meteorological factors and losses due to system components.

A carefully modelled PV system represents both types of losses accurately and realistically. PV system modelling should consider each aspect of the design and components to simulate the scenario that represents the actual conditions very closely.

PV System Design Using Conext CL125 Inverters

For easy access, the Conext CL inverter's latest datasheet and system component file (.OND file) is available with widely-used modeling software (PV syst) and databases. These files are also available for download on the Schneider Electric solar web portal.

When designing standard blocks, consider the following points. This Solution Guide will help to design DC and AC electrical components of balance for systems based on these points.

- Overall system impedance (Grid + Transformer + Cables) for parallel operation of inverters
- Voltage drop between Inverter and Point of connection to grid
- Inverter's response time to grid instability or faults (Active and Reactive power curtailments, Low and High Voltage Ride Through (LVRT and HVRT))
- Design of control and monitoring architecture

Large scale ground mount systems can be modeled and designed using standard system blocks comprising of Conext CL125 Inverters and user-defined PV modules and mounting solution.

A block of 2500kW (20 x 125) for ground mount solutions can be considered to multiply several times to achieve the required capacity. A standard block is designed once for all respective components and repeated several times in the installation. It reduces the effort and time required to design the complete solution and increases the flexibility and speed of construction. Manufacturing of components also becomes quicker as a standard block uses the available ratings of components and equipment. Ultimately, the overall design results in an optimized and reliable solution from all perspectives.

Building Blocks of a Decentralized PV System

For a modular design approach, we recommend following solution bricks or building blocks to design a decentralized PV power plant of size 2000 kVA using Conext CL125 Inverters.

Table 2-1 Decentralized PV system blocks

Brick	Description	Model	Supplier
Inverters	Conext CL125E	PVSCL125E	Schneider Electric
AC switch box (optional)	AC circuit breaker / switch	INS160–160A(3P) Switch Disconnect	Schneider Electric
	Surge protection device	---	---
	Terminal blocks	Linergy-NSYTRV	Schneider Electric
	Enclosure	---	---

Table 2-1 Decentralized PV system blocks

AC combiner box (4 inputs)	AC circuit breaker (MCBB)	NSX160-160A, Category A ,3P MCCB	Schneider Electric
	Terminal Blocks	Linergy-NSYTRV	Schneider Electric
	Main Bus bar	Copper, 600V, 50kA	External
	AC Disconnect switch	INS630-630A type switch-disconnect.3P	Schneider Electric External
	Grounding terminal and bus	---	External
	Surge protection device	---	SE or External
	Enclosure	---	
AC re-combiner box (4 inputs)	AC circuit breaker (MCCB)	Compact NSX630H- 630A with Micrologic 2.3, 3P	Schneider Electric
	Terminal Blocks	Linergy-NSYTRV	Schneider Electric
	Main Bus bar	Copper, 600V, 100kA	External
	AC Air circuit breaker	NW25H1 - ACB	Schneider Electric
	Grounding terminal and bus	---	External
	Surge protection device (optional)	---	External
	Enclosure	---	Schneider Electric or External
Transformer	LV-MV Dy11(or) DY0 Oil cooled / Dry type transformer	2000kVA, Oil immersed or Dry type, Z < 6%, 20000V/600V, Dy11 (or) DY0	Schneider Electric
MV ring main system	MV RM6 or Flusarc type switchgear units	RM6 NE-IDI or Flusarc CB-C, 24kV, 16kA	Schneider Electric
DC solar PV cables	DC UV protected cables	---	External
AC cables	AC LV and MV cables	---	External

Table 2-1 Decentralized PV system blocks

Communication and monitoring system	Complete third-party solution	---	Complete 3rd-party solution from: -Solar Log -Also Energy -Enerwise
Grounding system	Bonding cable Clamps & Connectors	---	External
DC combiner box	DC combiner box with Type 2 protection	External	Complete 3rd-party solution from: -Eaton India -Trinity Touch India -Weidmueller Germany

Positioning Inverters

⚠ DANGER

ELECTRICAL SHOCK AND FIRE HAZARD

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Inverter location

PV system design with Conext CL125E string inverters emphasizes the location of the Inverter in the complete solution. The balance of the system components and the inverter wiring box model might change depending on the location of the inverters and the length of the power cables connecting them with the AC combiners and re-combiners.

Primarily, four types of standard design blocks could be defined to fit almost all types of installations. Each option has advantages and disadvantages with respect to other installations but, for each instance, the respective option serves the purpose in the most efficient manner.

1. Inverters located on the PV field electrically grouped in an AC combiner box on the field – Inverters mounted on the PV panel structures and intermediate AC paralleling
2. Inverters grouped on the PV field by clusters “electrically” grouped in an AC combiner box on the field – Inverters mounted on dedicated structures connected to intermediate AC combiners
3. Inverters spread on the field – Inverters mounted on PV panel structures and AC paralleling in MV stations
4. DC distribution – Inverters close to the LV/MV substation on a dedicated structure and AC paralleling in the LV/MV substation

NOTE: Architecture option 1 and option 4 are recommended for the CL Inverter.

Option 1 (Inverters installed next to PV modules with first level AC Combiners)

Inverters located on the PV field “electrically” grouped in an AC combiner box on the field – Inverters mounted on the PV panel structures and intermediate AC paralleling.

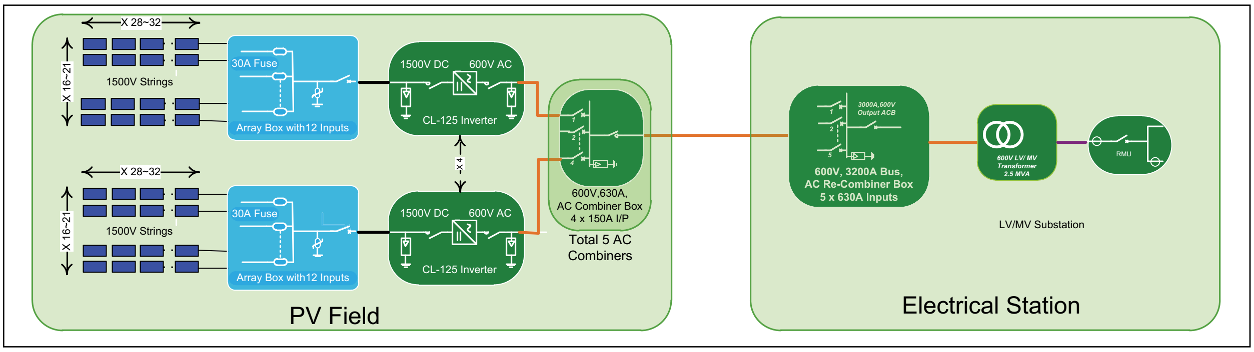

Figure 2-1 Standard block option 1

Advantages

- Fewer DC string cables
- Fewer DC I^2R losses
- High Flexibility for layout design
- No need of dedicated structure for Inverter mounting
- Inverters close to PV modules reducing electrified portion of system during fault
- Covers most of the usable space within boundary
- Schneider NSX160 type of breakers can be used in AC combiners – up to 4 inverters
- Integrated AC switch in CL Inverter eliminates the requirement of external AC switch immediately after inverter

Disadvantages

- Longer AC cables from the Inverter to first level of AC combiners
- Higher AC cable losses

Option 2 (Inverters installed next to AC combiner groups)

Inverters grouped on the field by clusters “electrically” grouped in an AC combiner box on the field – Inverters mounted on dedicated structures connected to intermediate AC combiners

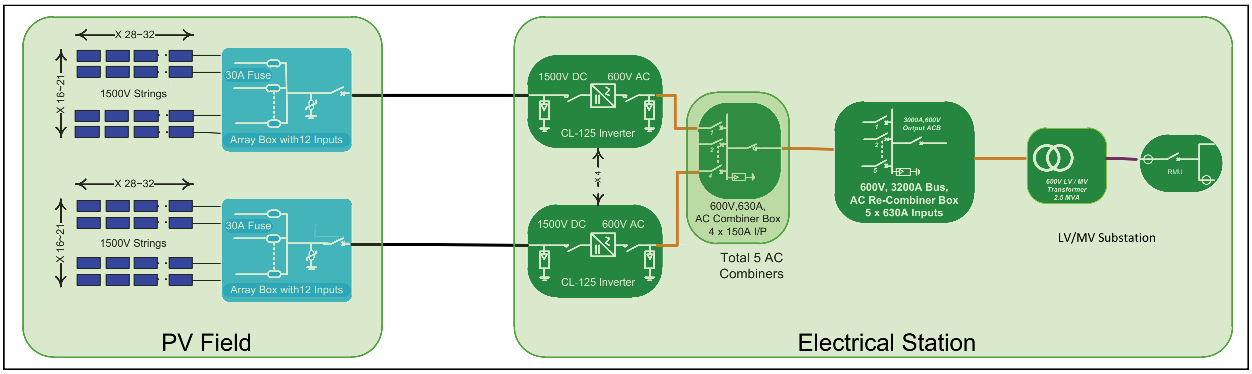

Figure 2-2 Standard block option 2

Advantages

- Shorter AC cables
- AC switch and external AC SPD not required if included in the AC combiner box
- Schneider NSX160 type of breakers can be used in AC combiners – up to 4 inverters

Disadvantages

- Longer DC string cables length might need higher size (cross section) of DC cable
- Dedicated mounting structures required for the Inverter and AC combiner mounting
- Higher DC cable losses

Option 3 (Inverters installed next to PV modules without first-level AC combiners)

Inverters spread on the field – Inverters mounted on PV panel structures and AC paralleling in MV stations.

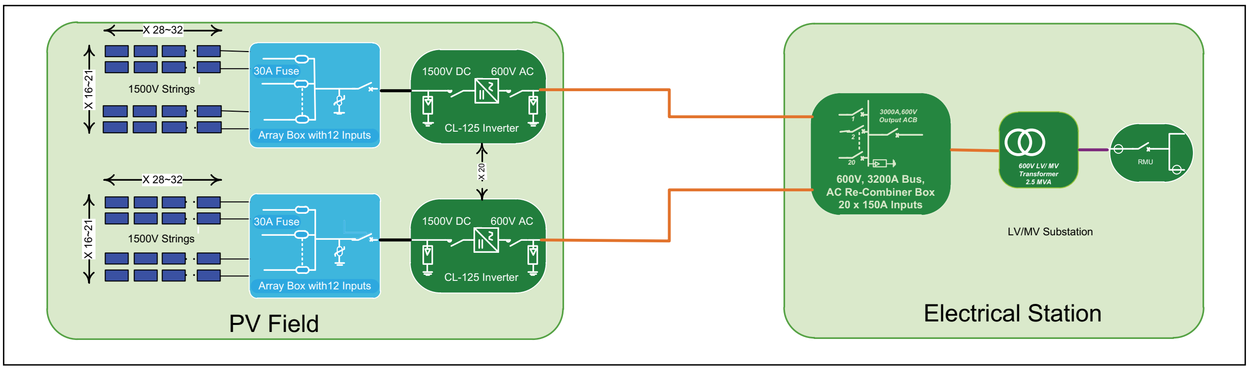

Figure 2-3 Standard block option 3

Advantages

- Shorter DC string cables
- Reduced DC I2R losses
- High Flexibility for layout design
- No need of dedicated structure for Inverter mounting
- Inverters close to the PV modules reducing the electrified portion of the system during a fault
- Covers most of the usable space within the boundary
- First level AC combiners eliminated resulting in cost savings

Disadvantages

- longer AC cables from Inverter to AC combiners
- High AC cable losses
- Increased size of AC cable will require higher size of terminal blocks in external AC combiner boxes
- High number of AC cables run from inverter to MV stations with increased time and chances of connection mistakes
- May need to use a Residual Current Monitoring (RCM) unit

Option 4 (Inverters installed next to LV/MV transformer)

DC distribution – Inverters close to LV/MV substation on a dedicated structure and AC paralleling in LV/MV substation.

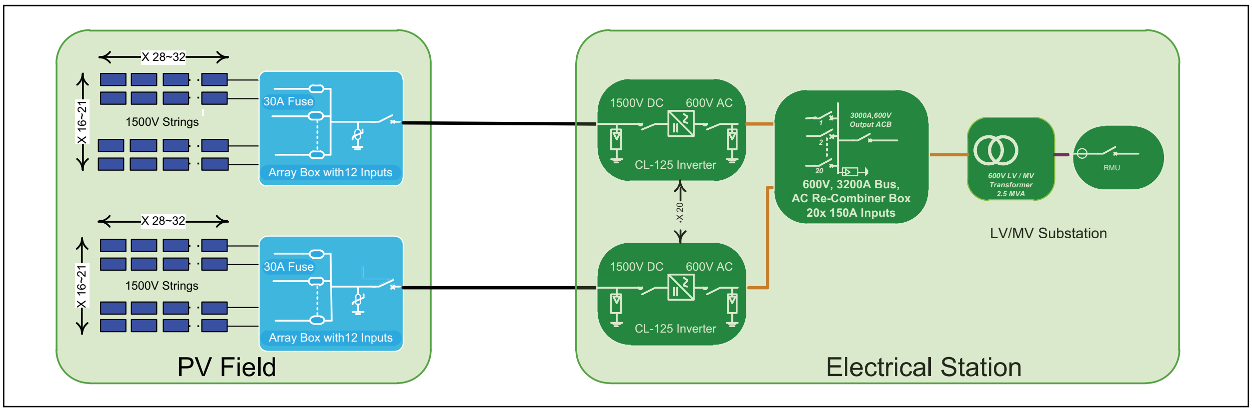

Figure 2-4 Standard block Option 4

Advantages

- Shorter AC cables
- High Flexibility for layout design
- AC switch and AC SPD not required if considered in the AC combiner box
- Easy access to the Inverters for service and maintenance
- RCD not required

Disadvantages

- Longer DC string cables might need to opt for higher size of DC cable
- External DC switch box with SPD required to protect long DC strings
- Combining DC strings might lose benefit of separate MPPT
- Dedicated structures required for Inverter and AC combiner mounting at MV station
- Higher DC cable losses

3 DC System Design

This chapter on DC Systems Design contains the following information:

- String and Array Sizing Rules

DC System Design

⚠ DANGER

ELECTRICAL SHOCK AND FIRE HAZARD

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DC system design comprises of Module and Inverter technology assessment, string sizing, Arrangement and interconnection of strings, string cable sizing and length management, DC combiner box sizing if required, string / array cable sizing and routing up to Inverter's terminal.

Out of the listed tasks, String sizing is the most important as many other decisions depend on it, such as type and size of module mounting tables, interconnection arrangements, and cable routing.

String and Array Sizing Rules

To calculate the string size:

1. Gather the following technical information:
   - The following technical parameters from the PV modules:
     - Model of PV module to include
     - Maximum open circuit voltage V_{oc}
     - Maximum array short circuit current I_{sc}
     - Maximum power point voltage V_{mpp} and current I_{mpp}
     - Temperature coefficients for Power, Voltage, and Current
   - The following technical parameters from the Inverter:
     - Full power MPPT voltage range of CL125E (860V–1250V)
     - Operating voltage range (860V–1450V)
     - Maximum DC short circuit current (240A)
   - The following weather data:
     - Highest and lowest temperature at the location of installation
     - TMY or MET data set for location
2. Understand and ensure the rules of string sizing
   - Series-connected modules should not have open-circuit voltage higher than the Maximum V_{oc} limit of the inverter.

     Number of modules per string x V_{oc} (at $t°_{min}$) < inverter V_{max}

- Combined short circuit current of all parallel connected strings should not be higher than the Short Circuit current rating of the inverter (i.e., 240A). This should include any derating as required by local codes for defining the maximum I_{sc}.

  I_{sc} strings < inverter I_{max}
- Series-connected modules should not have open circuit voltage lower than the lower limit of the MPPT voltage range of the Inverter (860V)

  Number of modules per string x V_{mp} (at $t°_{max}$) < inverter V_{min}

3. Calculate the Minimum Number of PV modules in Series
4. Calculate the Maximum Number of PV modules in Series
5. Calculate the total number of strings in Parallel

Definitions

The following table defines the terms, symbols and acronyms used in calculations.

Term	Description
Ns_{min}	Number of PV Modules in series at least
V_{min}	Minimum string voltage for maximum power point tracking
V_{max}	Maximum string voltage for maximum power point tracking
V_{maxr}	Maximum module voltage at minimum operating cell temperature
V_{oc}	Open circuit voltage of the panels
V_{minr}	Minimum module voltage at maximum operating cell temperature
φ	Coefficient of variation of voltage with temperature
V_{mpp}	Voltage at the point of maximum power
T	Temperature of the cell at STC
T_c	Temperature of the cell, ambient temperature
T_{amb}	Ambient temperature
I_{inc}	Incident radiation (maximum annual average)

Term	Description
NOCT	Nominal operating cell temperature NOCT conditions define the irradiation conditions and temperature of the solar cell, widely used to characterize the cells, PV Modules, and solar generators and defined as follows: Nominal Oper cell temp: 45±2 °C Irradiance: 800 W/m^2 Spectral distribution: Air Mass 1.5 G Cell temperature: 20°C Wind speed: 1 m/S
I_{sc}	Short circuit current of the module at STC
STC	Standard Test Conditions for measurement STC conditions define the irradiation conditions and temperature of the solar cell, widely used to characterize the cells, PV Modules and solar generators and defines as follows: Irradiance: 1,000 W/m^2 Spectral distribution: Air Mass 1.5 G Cell temperature: 25° C

Use Case Example

PV Module: A typical 315Wp Poly crystalline PV module parameters are considered

Inverter: Conext CL125E - 125kVA Inverter

Weather conditions: Maximum High Temperature is 36°C, Minimum Low Temperature is -25°C

	$\Delta V_{mpp}/T$ (φ)	V_{mpp}	V_{mpp} (70°C)	V_{oc}
315Wp Poly crystalline, 6-inch PV module	-0.31% / °C	36.6	31.49	45.1

	V_{mpp} Min (full power)	V_{oc}	I_{sc}
Conext CL125 Inverter	860V DC	1500V DC	240A DC

For a list of definitions, see “Definitions” on page 3–3.

Minimum Number of PV Modules

CL125E has a start up voltage of 920 V and an operating MPPT window from 860V to 1250V. The minimum number of modules per PV string is important to ensure that 860V remains the output voltage and the Inverter gets early start up as much as possible.

For a list of definitions of terms used in the calculations, see “Definitions” on page 3–3.

At 36 °C ambient temperature, to determine the temperature of the cell in any situation, the following formula could be used.

$T_c = T_{amb} + (I_{inc}\ (w/m^2)\ *\ (NOCT–20)/800)$

$\mathbf{T_c = 36°C + ((1000) * (47 – 20) / 800)) = 70°C}$

To calculate the V_{mpp} of the module at the maximum temperature 70 °C, we use:

$V_{mpp}(70°C)= V_{mpp\ (25°C)} – (T \times V_{mpp\ (25°C)} \times Ø/100)$

$\mathbf{V_{mpp}(70°C)= 36.60V – (45 \times (36.60V \times 0.31\% / 100)) = 31.49\ V\ @\ 70\ °C}$

To determine the temperature of the cell at STC, we use:

$T= T_c – T_{stc}$

T= (70 – 25) °C = 45 °C

With this data we can calculate the minimum number of PV Modules to be connected in series to maintain full nameplate power

$Ns_{min} = (V\ min / V_{mpp}\ (70°C))$

$\mathbf{Ns_{min} = (860 / 31.49) = 27.31}$

Rounding it up, **the answer is 28**. This is the minimum amount of PV Modules to be placed in series with each string to ensure the functioning of the inverter at 1000 W/m^2 and 36°C ambient temperature.

Maximum Number of PV Modules

The maximum number of PV modules in a string for the CL125E inverter is a ratio of the highest system voltage (1500V) to the Maximum open circuit voltage at the lowest temperature.

For a list of definitions of terms used in the calculations, see “Definitions” on page 3–3.

At - 25°C, to calculate the temperature needed for V_{oc}, we use:

$T = T_{amb} - T_{stc}$

T **= -25°C -25°C = -50°C**

To calculate the Voc of the string at minimum temperature of -25°C

$V_{OC\ (-25°C)}= V_{oc\ (25°C)} – (T \times V_{OC\ (25°C)} \times Ø)$

$\mathbf{V_{OC\ (-25°C)} = 45.1V – (-50 \times (45.10V \times 0.31\% / 100)) = 52.1\ V\ @\ -25°C}$

With this data we can calculate the maximum number of PV Modules to be connected in series to ensure the 1500V system sizing limit

$Ns_{max} = (V_{max} / V_{max}\ r)$

Ns_{max} = (1500 / 52.1) = 28.79

Rounding it down, the answer will be **28**. This is the maximum amount of PV Modules to be placed in series with each string to ensure the functioning of the inverter at 1000 W/m^2 and -25°C ambient temperature.

Table 3-1 Voltage correction factors

Lowest-Expected Ambient Temperature °C °F		Temperature Correction Factor
0 to 4	32 to 40	1.10
-1 to -5	23 to 31	1.12
-6 to -10	14 to 22	1.14
-11 to -15	5 to 13	1.16
-16 to -20	4 to -4	1.18
-21 to -25	-5 to -13	1.20
-26 to -30	-14 to -22	1.21
-31 to -35	-23 to -31	1.23
-36 to -40	-32 to -40	1.25

Number of Strings in Parallel

The maximum number of strings installed in parallel connected to Conext CL125E inverters, will be calculated as follows:

Number of Strings = I_{sc} Inverter max / (I_{sc})

Max. # of parallel strings = 240A / 9.18A = 26.14 strings

Rounding it down to **24 strings**

Since we have a physical connection limit of 12 (due to 12 DC string input in the DC combiner box), we will use all 12 inputs.

Table 3-2 shows an example of highest String sizing ratios with widely used PV module ratings.

Table 3-2 Example of highest string sizing ratios

PV Module type & rating	Poly Crystalline 315W	Mono Crystalline 265W
PV module series number	28	32
# of parallel strings	21	21
Total DC Power	185,220W	178,080W
Inverter rated power	125,000W	125,000W
DC/AC ratio	1.48	1.42

Optimum DC-AC Ratio

DC Ratio is based on STC conditions, but does not consider the specific configuration of the project. The performance is a function of location and racking style. For example, a highly optimized system such as a 2-Axis tracker will have a much higher performance advantage compared to a 5-degree fix tilt. Likewise, a strong solar irradiance region will have a much higher energy potential than a weaker region. The amount of clipping losses will be based on the amount of relevant energy available vs. the inverter nameplate. As clipping exceeds 3%, there may be diminishing value to higher levels of DC Ratio.

Table 3-3 lists suggested DC oversizing ranges for the Conext CL125 Inverter with various racking styles and locations.

Table 3-3 Conext CL125 Inverter suggested DC oversizing range

Racking Style (location)	DC Oversizing Range
Steep Fix tilt (ground mount applications)	1.25 – 1.35
1-Axis Tracked (ground mount applications)	1.20 – 1.30
2-Axis Tracked (ground mount applications)	1.10 – 1.20

Schneider Electric recommends a limit of 1.5 as a maximum. Higher DC/AC ratios will require review by a Schneider Electric applications engineer.

1. The Conext CL125E has a single PV input with a direct connection from the Combiner Box. This Conext CL125E PV input can accept a cable size of maximum 200mm^2.
2. The Conext CL external DC Combiner can be designed with 30A fuses mounted on both polarities. While DC inputs are connected with Y connectors to combine two strings to each input, 15A in-line fuses should be considered (see *Figure 3-2*). Designers and Installers must consider this in the preliminary design.

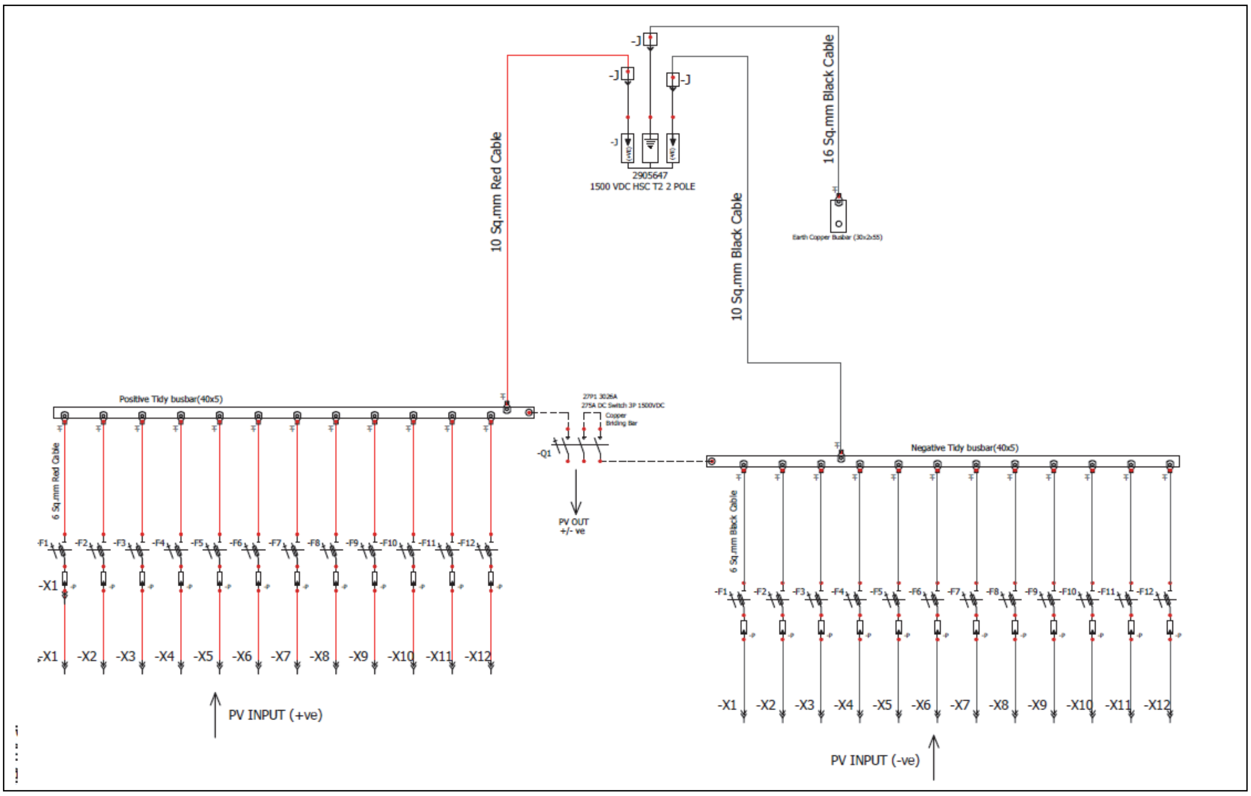


Figure 3-1 Typical DC Combiner circuit diagram of the CL Inverter

NOTICE
EQUIPMENT DAMAGE Use only compatible Amphenol H4 mating connectors with the specified part numbers. Using mismatched connectors can cause corrosion and hotspots. **Failure to follow these instruction can cause equipment damage.**

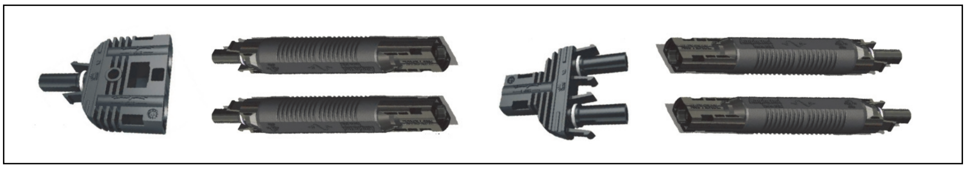


Figure 3-2 Y-type connectors with in-line 15A fuse

Recommended basic rules for string formation

1. Select an EVEN number for modules in a string to have simpler string interconnectivity over mounting structures.
2. Try to maximize modules per string within V_{oc} and V_{mpp} limits of the Inverter.
3. Formation of strings should be designed in a way that cable management at the back of modules could be followed as per electrical installation rules and with shortest string cable length as well as minimum bends.

4. Support the connectors and avoid a sharp bend from the PV Module cable box.
5. If possible, keep the PV module strings connected and formed in horizontal lines to avoid row shadow impact on all strings in each wing of racks or trackers.
6. Follow the instructions of the PV module manufacturer to select portrait or landscape position of modules.
7. Do not combine separate ratings of PV modules in one string.
8. The CL125E inverter is a transformer-less inverter, so it cannot be used with grounded arrays. This inverter is designed only for floating/ungrounded arrays. Before finalizing your PV system design, contact the PV module manufacturer.

4 AC System Design

This chapter on AC Systems Design contains the following information:

- AC System Design
- AC Component Design

AC System Design

⚠ DANGER

ELECTRICAL SHOCK AND FIRE HAZARD

Installation including wiring must be done by qualified personnel to ensure compliance with all applicable installation and electrical codes including relevant local, regional, and national regulations. Installation instructions are not covered in this Solution Guide but are included in the relevant product manuals for the Conext CL125 Inverter. Those instructions are provided for use by qualified installers only.

Failure to follow these instructions will result in death or serious injury.

The AC system of a PV plant consists of an AC switch box (optional), AC combiner box, AC re-combiner box, AC Cables, trenches, LV-MV Transformer, Ring main units at MV stations in PV field, MV cable circuit and MV station at Grid Box.

AC low voltage circuits with a high amount of power needs extreme care to achieve reliability, safety and the highest level of availability of the system. Selection of circuit breakers (MCB and MCCBs), Disconnect switches, Protection devices and cables is the key to achieve all three objectives.

Safety and availability of energy are the designer's prime requirements.

Coordination of protection devices ensures these needs are met at optimal cost.

Implementation of these protection devices must allow for:

- the statutory aspects, particularly relating to safety of people
- Technical and economic requirements

The chosen switchgear must:

- withstand and eliminate faults at optimal cost with respect to the necessary performance
- limit the effect of a fault to the smallest part possible of the installation to ensure continuity of supply

Achievement of these objectives requires coordination of protection device performance, necessary for:

- managing safety and increasing durability of the installation by limiting stresses
- managing availability by eliminating the fault by means of the circuit breaker immediately upstream.

The circuit breaker coordination means are:

- Cascading
- Discrimination

If the insulation fault is specifically dealt with by earth leakage protection devices, discrimination of the residual current devices (RCDs) must also be guaranteed.

Circuit Breaker Coordination

The term coordination concerns the behavior of two devices placed in series in electrical power distribution in the presence of a short circuit.

Cascading or backup protection

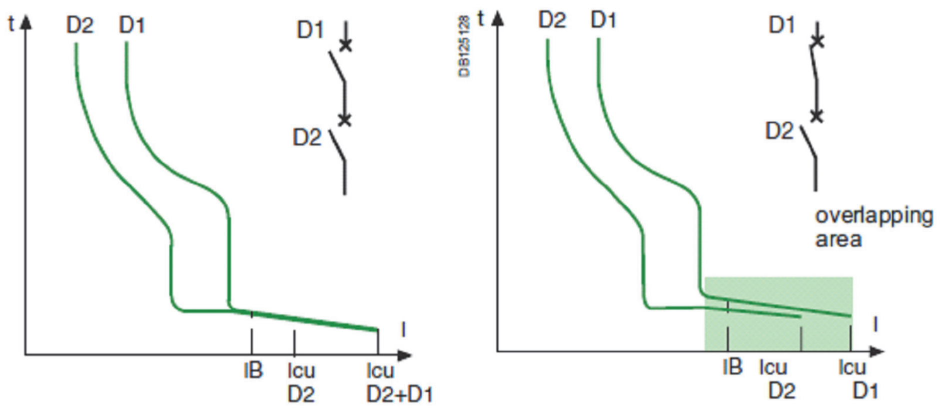
Cascading or backup protection consists of installing an upstream circuit breaker **D1** to help a downstream circuit breaker **D2** to break short-circuit currents greater than its ultimate breaking capacity **Icu D2**. This value is marked **Icu D2+D1**.

Standard IEC 60947-2 recognizes cascading between two circuit breakers. For critical points, where tripping curves overlap, cascading must be verified by tests.

Discrimination

Discrimination consists of providing coordination between the operating characteristics of circuit breakers placed in series so that should a downstream fault occur, only the circuit breaker placed immediately upstream of the fault will trip.

Standard IEC 60947-2 defines a current value Is known as the discrimination limit such that, if the fault current is less than this value **Is**, only the downstream circuit breaker **D2** trips. If the fault current is greater than this value **Is**, both circuit breakers **D1** and **D2** trip. Just as for cascading, discrimination must be verified by tests for critical points.



Glossary:

- Isc(D1): Short-circuit current **at the point where D1** is installed
- IcuD1: Ultimate breaking capacity **of** D1.

	MSB Level A	Subdistribution switchboard Level B
Switchboard data		
Nominal I	1000 to 6300 A	100 to 1000 A
Isc	50 kA to 150 kA	20 kA to 100 kA
Thermal withstand Icw / EDW	***	*
Continuity of supply	***	***
Circuit-breaker type	High current power circuit-breaker or moulded case circuit-breaker	Moulded case circuit-breaker
		
Standard IEC 60947-2	■	■
Trip unit		
Thermal magnetic		□ (2)
electronic	■	■
Product data		
Standard In	800 to 6300 A	100 to 630 A
Icn	50 kA to 150 kA	25 kA to 150 kA
Utilisation category	B	A
Limiting capacity	* (3)	***

■ recommended or compulsory
□ possible
*** important
** normal
* not very important

(1) For domestic use as per IEC 60898 standard.
(2) Possible up to 250 A.
(3) Le Sizing of the switchboard at level A means that this characteristic is not very important for standard applications.

Figure 4-1 Summarizing Table

Note: Discrimination and cascading can only be guaranteed by the circuit breaker manufacturer.

Installation standard IEC 60364 governs electrical installations of buildings. National standards, based on this IEC standard, recommend good coordination between the protection switchgear. They acknowledge the principles of cascading and discrimination of circuit breakers based on product standard IEC 60947-2.

For more details on Limitation, Cascading and Discrimination of circuit breakers, refer to Schneider Electric's Low voltage Expert Guide No.5 – "Coordination of LV protection devices".

AC Component Design

Right after Conext CL inverter AC terminals, an AC switch box should be installed depending on the distance from the first AC combiner.

The AC Switch Box (Optional)

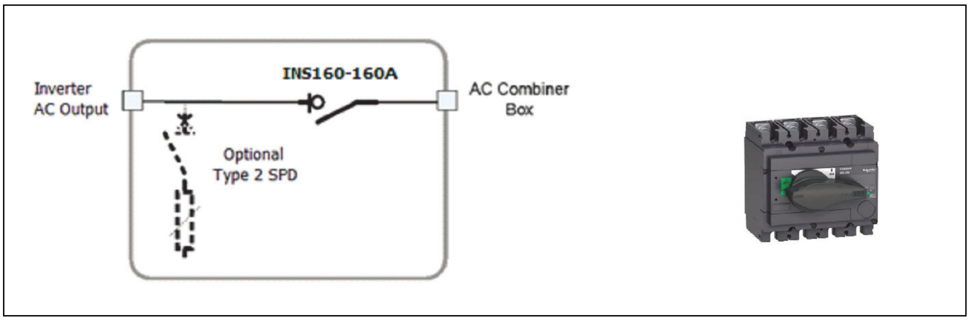


Figure 4-2 AC Switch Box Schematic Diagram

Function

1. INS160-160A switch disconnects the inverter from the AC combiner.
2. Type 2 SPD protects the inverter against voltage surges coming from AC lines.

Typical use

1. The AC box is optional, but is necessary when:
    - the distance or an obstacle between the inverter and the AC combiner box prevents the safe disconnection of the inverters at the AC combiner box level
2. AC box is located near the inverter
    - generally needs an outdoor enclosure
3. Possible long distance between the Inverter and the AC combiner box
    - If the cross section area of the outgoing cable is higher than 200mm^2 (maximum cross-section of the cables at the AC terminal of the Inverter), the AC switch box could be helpful to host a higher-sized cable between the AC combiner and the Inverter.

Advantages of the offer

1. Two possible configurations of the AC box:
    - with surge protection
    - without surge protection
2. Possibility to increase the cross-section cables to reduce AC losses - output cable terminals up to 185mm^2. The circuit breaker's direct cable connectable size is lower and a higher size would need separate terminal blocks in the AC combiner, as well as in the AC switch box, if required due to a high voltage drop.
3. Range for 125kW (125kVA)

AC Cable sizing

The output terminal block of the CL125E inverter can host up to 185mm^2 Copper or Aluminum cable. Recommended cable types are 3 core for L1, L2, L3 and 4 core for additional PE connection.

The AC Cable sizing calculation includes ampacity, voltage drop, short circuit calculation and thermal de-rating of AC cables.

The total power loss due to AC cables must be designed to be <1%. To achieve this level, it is important to select a suitable cable size with the required ampacity, short-circuit rating, voltage grade and with low voltage drop.

Formulae commonly used to calculate voltage drop in a given circuit per kilometer of length.

$$\Delta U = \sqrt{3} Ib(R\cos\phi + X\sin\phi)L$$

$$\%Vd = \frac{100\Delta U}{Un}$$

Where:

- X – inductive reactance of a conductor in Ω/km
- ϕ – phase angle between voltage and current in the circuit considered
- Ib – the full load current in amps
- L – length of cable (km)
- R – resistance of the cable conductor in Ω/km
- Vd – voltage drop
- Un – phase to neutral voltage

AC cable sizes between Conext CL125 Inverters and AC combiner boxes will mostly depend on the distance between them. The maximum output current of the Conext CL125 Inverter is 120 A. Considering the de-rating factors due to cable laying methodology and thermal de-rating due to conduits, mostly 240kcmil 3 core AL cable fits in to the most instances.

Table 4-1 provides recommended maximum cable lengths from inverter to AC distribution box. We advise the installer to carry out a detailed cable sizing calculation specifically for each inverter to calculate the power loss associated with the suggested cable sizes.

Table 4-1 Suggested sizes of AC cables with length

AC Cable length	AC Cable size (mm^2) A
1-50m	90
50-100m	120
>100m	150 or higher

It is essential to calculate and consider the correct fault level on each combiner bus level to select the right size of cable, MCB, MCCB and RCD, Surge protection and Disconnect devices.

The following methodology can help to understand this calculation.

If the AC cable length exceeds 10 m (32.8ft), the use of an AC switch box closer to the inverter is recommended. This switchbox can be used to connect a higher size of AC output cable, if required to avoid voltage drop.

It is important to consider both resistive and reactive components of voltage drop when calculating cable sizing. The Reactive component of cable Impedance plays an essential role in parallel operation of Inverters. The target should be to reduce the reactive impedance as much as possible to increase the number of parallel connected inverters at the LV winding of the Transformer (considering intermediate AC distribution boxes).

AC Combiner Box

AC combiner box is first level combiners, mostly located in the PV field in large utility scale projects. AC combiner box houses the first level protection for Inverters on the AC side.

Function

1. Combines AC currents coming from several inverters.
2. Isolates the combiner box from the AC line.
3. Output - Circuit Breaker.
4. Circuit breaker (according to prospective current).
5. Protects inverters against voltage surges from the AC line.
6. iPRD range for surge protection.

Typical use

1. AC combiner box is located near the inverters.
2. Long distance between the AC combiner box and the AC distribution box.
3. Requires high cross-section terminals for output cabling.

Depending on the number of inverters being combined at AC combiner's bus-bar, the incoming lines can be protected using MCBs or MCCBs. Selection of this component depends on rated circuit current, expected fault current, fault clearing time and remote operation requirements. Length of cable connected between AC combiner output and AC re-combiner input plays an important role as a longer length reduces the fault current to break. See the following example circuit.

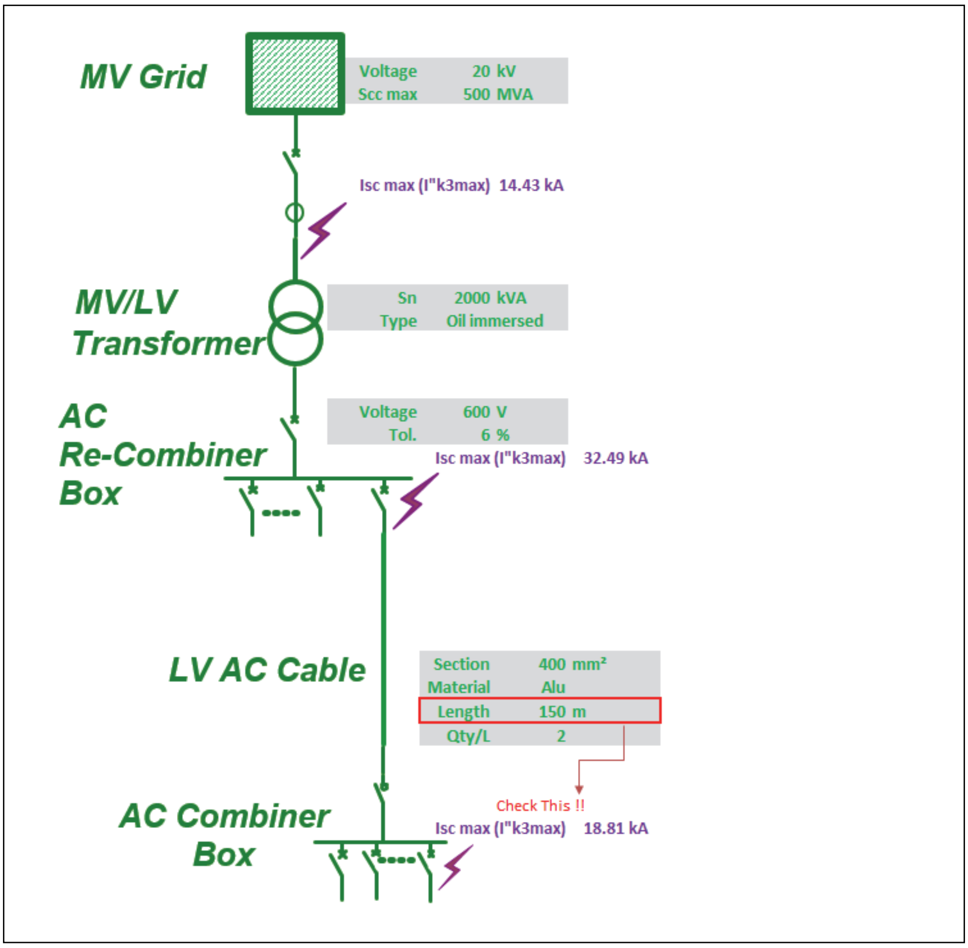


Figure 4-3 Example circuit with 150m cable

The example circuit in Figure 4-3 has 150m length from the AC combiner to the AC re-combiner. The resulting fault level at the AC combiner bus-bar is 18.81kA and choice of Breaker is NSX160 - 160 A - 3 MCCB with >25kA Breaking capacity.

Now, let's increase the length of the cable to 250m and check again.

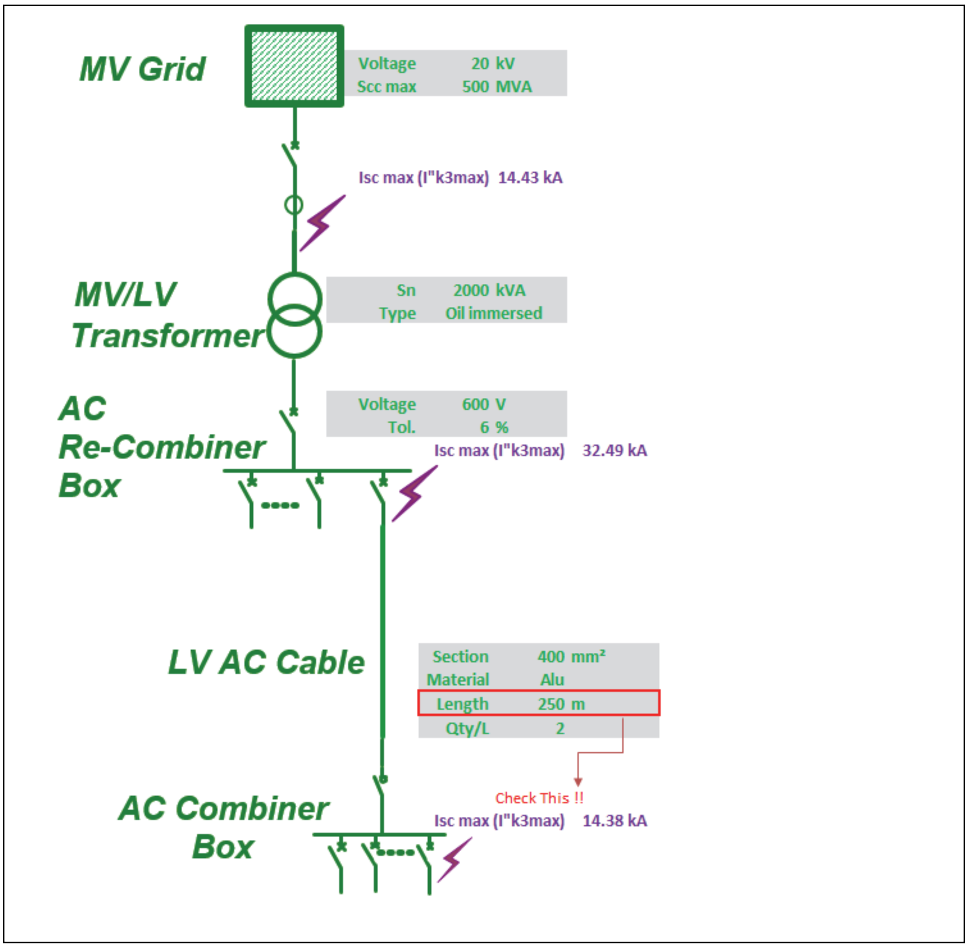


Figure 4-4 Example circuit with 250m cable

In the example circuit in Figure 4-4, the fault current is reduced to 14.38kA allowing the selection of NSX160 - 160 A - 3 MCCB with >20kA breaking capacity.

Methodology to calculate the fault level at AC combiner bus-bar

For a combiner box connected to a re-combiner box with 400mm^2 size AL cable of 250m length and the re-combiner box connected to a 2000kVA 20kV/600V, 6% transformer.

Fault level at the AC combiner bus-bar:

$$= \text{Voltage} \times \frac{\text{Voltage Correction Factor C}}{\text{Fault Impedance}}$$

$$= 600 \times \frac{1.05}{(Z_{GRID} + Z_{TR-LV} + Z_{CABLE}) \times \sqrt{3}}$$

$$= 600 \times \frac{1.05}{\{(R_{GRID} + R_{TR-LV} + R_{CABLE})^2 + (X_{GRID} + X_{TR-LV} + X_{CABLE})^2\}^{1/2} \times \sqrt{3}}$$

Let's calculate the transformer LV Impedance for a 2000KVA, 20kV/600V transformer with the following values:

Voltage factor: c=1.05
Short circuit impedance: 6%
Total loss (no-load and full load): 19450W

Before we calculate the transformer LV impedance, it's important to know the following definitions:

Term	Definition
C_{max}	Voltage factor for calculating the maximum short circuit current
I_{rT}	Rated current of the transformer on the low or high voltage side
K_T	Impedance correction factor. A network transformer connects two or more networks at different voltages. For two winding transformers this impedance correction factor should be used when calculating the short circuit impedance.
P_{krT}	Total loss in the transformer windings at the rated current
S_{rT}	Rated apparent power of the transformer
U_{kr}	Short circuit voltage at the rated current
U_{rT}	Rated voltage of the transformer on the low or high voltage side
x_t	Relative reactance of transformer
X_{TR-LV}	LV winding Reactance of the transformer

Before we calculate the transformer LV impedance, we will calculate K_t and X_T using $C_{max.}$

Voltage Factor (c):

Table 4-2 Voltage Factor c

	Voltage factor c for the calculation of	
Nominal voltage U_n	**maximum short-circuit currents c_{max}[a]**	**minimum short-circuit currents c_{min}**
Low voltage 100 V to 1,000 V (IEC 60038, table I)	1.05[b] 1.10[c]	0.95

Table 4-2 Voltage Factor c

Nominal voltage U_n	Voltage factor c for the calculation of maximum short-circuit currents c_{max}[a]	Voltage factor c for the calculation of minimum short-circuit currents c_{min}
Medium voltage >1 kV to 35 kV (IEC 60038, table III)	1.10	1.00
High voltage[d] >35 kV (IEC 60038, table IV)		

a. $c_{max}U_n$ should not exceed the highest voltage U_m for equipment of power systems
b. For low-voltage systems with a tolerance of +6 %, for example systems renamed from 600 V.
c. for low-voltage systems with a tolerance of +10 %
d. If no nominal voltage is defined $c_{max}U_n = U_m$ or $c_{min}U_n = 0.90 \times U_m$ should be applied.

Impedance Correction Factor:

$$K_T = 0.95\frac{c_{max}}{1 + 0.6x_t}$$
$$= 0.96328045$$

Transformer LV Impedance:

$$Z_T = \frac{u_{kr}}{100\%} \times \frac{U_{rT}^2}{S_{rT}}$$
$$Z_{TR-LV} = K_T \times 600 \times 600 \times 0.06/2000 \times 1000$$
$$= 0.010403429\Omega$$
$$R_T = \frac{u_{kr}}{100\%} \cdot \frac{U_{rT}^2}{S_{rT}} = \frac{P_{krT}}{3I_{rT}^2}$$
$$R_{TR-LV} = K_T \times \frac{\text{Losses kW}}{3(\text{Rated Current})^2}$$
$$= K_T \times \frac{19450}{3 \times (2000 \times 1000/600/1.73)^2}$$
$$= 0.001686124\Omega$$
$$X_T = \sqrt{Z_T^2 - R_T^2}$$
$${}_{TR-LV} = K_T \times \sqrt{Z^2 - R^2}$$
$$= 0.010265881\Omega$$

Cable Impedance:

$$Z_{CABLE} = \sqrt{R_{CABLE^2} + X_{CABLE^2}}$$

$$R_{CABLE} = \text{Resistance @ } 90°C \times \frac{length}{runs} \times 1000 = 0.0124$$

$$X_{CABLE} = \text{Reactance} \times \frac{length}{runs} \times 1000 = 0.00991$$

400	mm^2 Cable
R (Ohms/km)	0.01239938
X (Ohms/km)	0.00991171
Length	250
Runs	2
Type	Alu

Grid LV Impedance:

Considering the MV connection at 20kV and the Grid short circuit power or 500MVA, we will use the following values to calculate the Grid impedance at the LV side of the transformer.

MV voltage: 20kV
Short circuit power from grid: 500MVA
Transformer factor C for MV grid: 1.1
Size of transformer: 2000KVA

First we need to calculate MV impedance.

$$Z_{MV-GRID} = (R^2_{MV-GRID} + X^2_{MV-GRID})^{1/2}$$

$$Z_{MV-GRID} = \frac{c \times \text{Grid voltage}}{\text{Grid current}}$$

$$= 1.1 \times 20000/(500 \times 10^6/20000 \times \sqrt{3})$$

$$= 0.88\Omega$$

$$X_{MV-GRID} = 0.995 \times Z_{MV-GRID}$$

$$= 0.995 \times 1,5224$$

$$= 0.8756$$

$$R_{MV-GRID} = (Z^2_{MV-GRID} - X^2_{MV-GRID})^{1/2}$$

$$= 0.08788993\Omega$$

Then, calculate Grid LV impedance from Grid MV values:

$$X_{LV-GRID} = X_{MV-GRID}\left(\frac{LV\ Voltage^2}{MV\ Voltage^2}\right)$$

$$= 0.8756\left(\frac{600^2}{20000^2}\right)$$

$$= 0.000788\Omega$$

$$R_{LV-GRID} = R_{MV-GRID}\left(\frac{LV\ Voltage^2}{MV\ Voltage^2}\right)$$

$$= 0.08788993\left(\frac{600^2}{20000^2}\right)$$

$$= 7.91 \times 10^{-5}\Omega$$

Fault level at AC combiner bus bar:

$$= 600 \times \frac{1.05}{\{(R_{LVgrid} + R_{TR-LV} + R_{CABLE})^2 + (X_{LVgrid} + X_{TR-LV} + X_{CABLE})^2\}^{1/2} \times \sqrt{3}}$$

$$= 600 \times \frac{1.05}{\{0.013183963^2 + 0.014824554^2\}^{1/2} \times \sqrt{3}}$$

$$= 14.38kA$$

Selected circuit breaker for AC combiner incomers

So for this scenario Figure 4-5 shows the calculated fault current for circuit breakers selection.

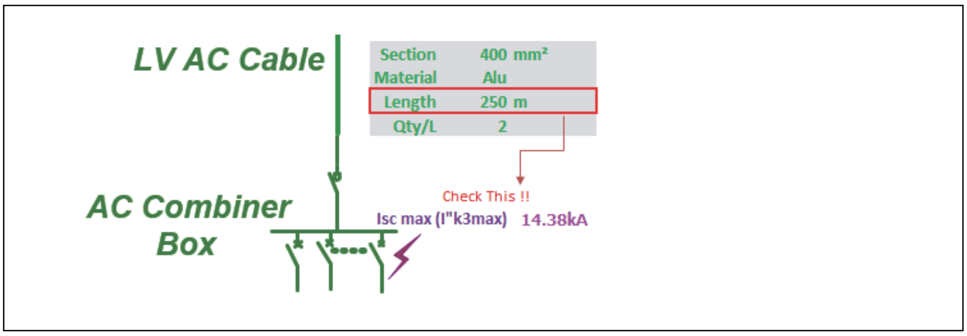


Figure 4-5 Calculated fault current for circuit breakers selection

Recommended circuit breaker for AC combiner incomers

The above example is ending with around 14.38kA. Generally, the fault level on the AC combiner bus is within the range of >20 to 30kA. For this application, we recommend using NSX160L-160A or higher category breakers to ensure the minimum 20kA fault current rating at the AC combiner level.

Device short name	NSX160L-160A
Poles description	3P
[I_n] rated current	160 A at 40°C
Network type	AC
Trip unit technology	Thermal-magnetic
Breaking capacity	20 kA at 660/690VAC
Utilization category	Category A
Suitability for isolation	Yes
Network frequency	50/60 Hz
[I_{cs}] rated service breaking capacity	14.38 kA 75% x I_{cu}
[U_i] rated insulation voltage	690 V AC
[U_{imp}] rated impulse withstand voltage	8 kV
Contact position indicator	Yes

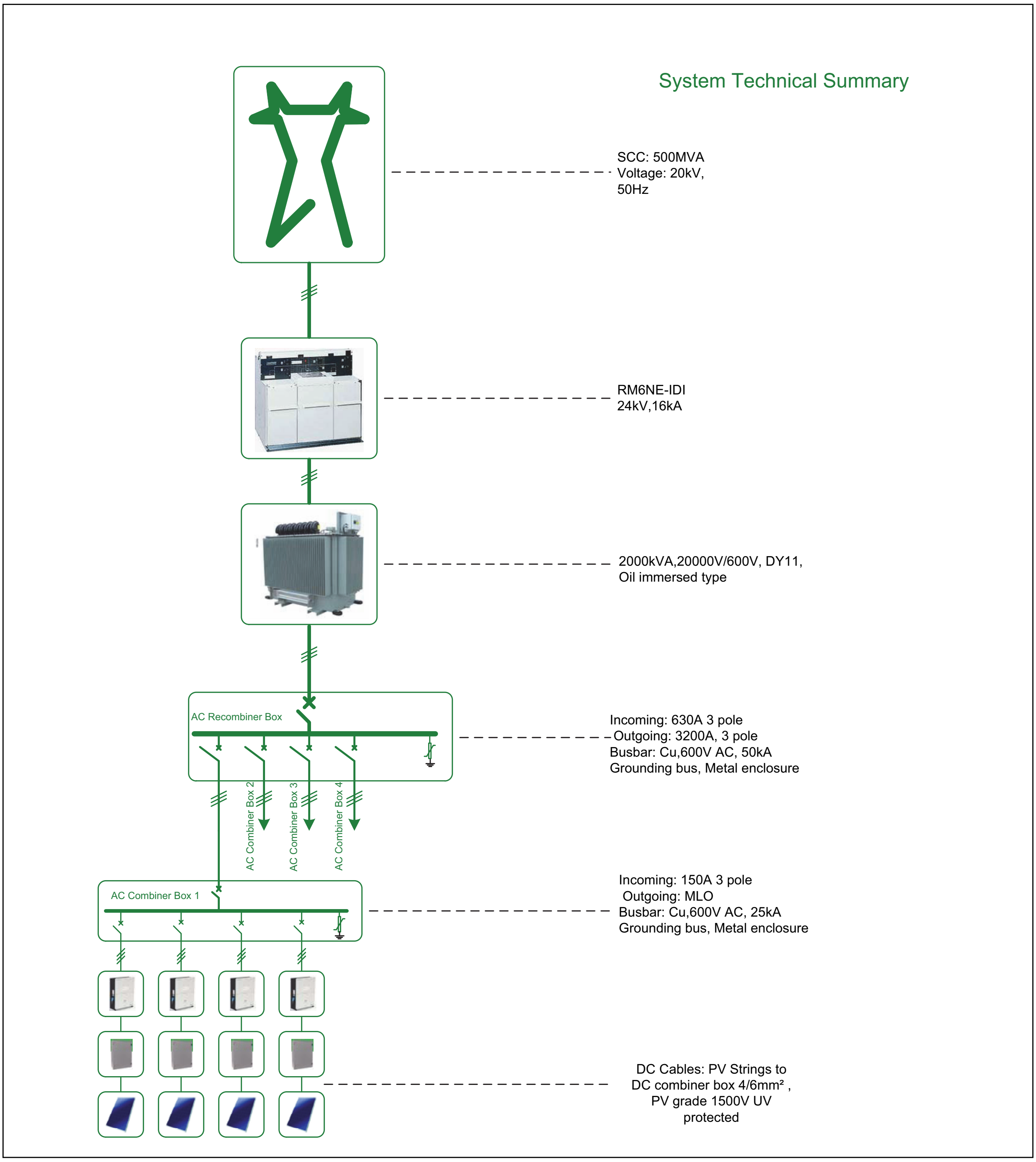
Recommended Switch Disconnect for AC Combiner Outgoing

The selection of a switch-disconnect for the AC combiner box also depends on the fault current and nominal continuous current that the AC combiner box is going to handle.

Like for an AC combiner box combining four Conext CL125 Inverters ($4 \times 125\text{kW} = 500\text{kW}$), the operating current can be as high as 480 A $500 \times 1000/(600\text{V} \times \sqrt{3})$. Considering the operating margin, a 630 A switch-disconnect that can withstand up to 25kA fault current would be a good choice for this example. The Compact INS630 type switch-disconnect can be used.

Device short name	Interpact INS630
Poles description	4P
Network type	AC
Network frequency	50/60 Hz
[Ie] rated operational current	630 A
[Ui] rated insulation voltage	750 V
[Uimp] rated impulse withstand voltage	8 kV
[Icm] rated short-circuit making capacity	50 kA
[Ue] rated operational voltage	690 V AC
Suitability for isolation	Yes
Contact position indicator	Yes

Example: Recommended block architecture with four input AC combiners



AC Re-combiner Box

AC re-combiner box re-combines all AC combiner boxes at one bus-bar and accumulated power flows to the transformer LV winding to get transferred to the MV network.

The AC re-combiner box is usually located at an LV-MV station inside the kiosk or outside on a concrete pad. All incomers from AC combiners in the PV field are connected to the molded case type circuit breakers. The Outgoing to the LV transformer winding from the AC re-combiner box can be connected to either an MCCB or an Air circuit breaker (ACB) depending on the space requirements.

Selection of the MCCB and ACB should follow similar rules described for AC Combiners. It is worth noting that discrimination and cascading of circuit breakers help to design a more accurate protection philosophy, as well as to save on capital costs due to the reduced fault level capacity of components.

The fault level at the transformer's LV terminal will be mostly the same as the fault level on the AC re-combiner's bus-bar due to the short distance between the Transformer and the re-combiner panel.

Grid MV and LV Impedance Values

Considering the MV connection at 20kV and Grid short circuit power of 500MVA, we will use following values to calculate Grid impedance at the LV side of the transformer.

MV voltage: 20kV
Short circuit power from grid: 500MVA
Transformer LV voltage: 600V
Voltage factor c for MV grid: 1.1
Size of transformer: 2000KVA

First, calculate MV impedance:

NOTE: In the following calculations, c=voltage factor. For more information about voltage factors, see "Voltage Factor (c):" on page 4–19.

$$Z_{MV-GRID} = (R^2_{MV-GRID} + X^2_{MV-GRID})^{1/2}$$

$$Z_{MV-GRID} = \frac{c \times \text{Grid voltage}}{\text{Grid current}}$$

$$= 1.1 \times 20000/(500 \times 10^6/20000 \times \sqrt{3})$$

$$= 0.88\Omega$$

$$X_{MV-GRID} = 0.995 \times Z_{MV-GRID}$$

$$= 0.995 \times 0.88$$

$$= 0.8756$$

$$R_{MV-GRID} = (Z^2_{MV-GRID} - X^2_{MV-GRID})^{1/2}$$

$$= 0.08788993\Omega$$

Then, calculate Grid LV impedance from Grid MV values:

$$X_{LV-GRID} = X_{MV-GRID}\left(\frac{\text{LV Voltage}^2}{\text{MV Voltage}^2}\right)$$

$$= 0.8756\left(\frac{600^2}{20000^2}\right)$$

$$= 0.000788\Omega$$

$$R_{LV-GRID} = R_{MV-GRID}\left(\frac{\text{LV Voltage}^2}{\text{MV Voltage}^2}\right)$$

$$= 0.08788993\left(\frac{600^2}{20000^2}\right)$$

$$= 7.91 \times 10^{-5}\Omega$$

Transformer Impedance Values

For a 2000KVA, 20kV/600V transformer with the following values:

Voltage factor: c=1.05
Short circuit impedance: 6%
Total losses (No-load and Full load): 19450W

When calculating transformer impedance values, it's important to know the following definitions:

Term	Definition
C_{max}	Voltage factor for calculating the maximum short circuit current
I_{rT}	Rated current of the transformer on the low or high voltage side
K_T	Impedance correction factor. A network transformer connects two or more networks at different voltages. For two winding transformers this impedance correction factor should be used when calculating the short circuit impedance.
P_{krT}	Total loss in the transformer windings at the rated current
S_{rT}	Rated apparent power of the transformer
U_{kr}	Short circuit voltage at the rated current
U_{rT}	Rated voltage of the transformer on the low or high voltage side
x_t	Relative reactance of transformer
X_{TR-LV}	LV winding Reactance of the transformer

Before we calculate the transformer LV impedance, we will calculate K_t and X_T using $C_{max.}$

Voltage Factor (c):

Table 4-3 Voltage Factor c

Nominal voltage U_n	**Voltage factor c for the calculation of**	
	maximum short-circuit currents c_{max}[a]	**minimum short-circuit currents c_{min}**
Low voltage 100 V to 1,000 V (IEC 60038, table I)	1.05[b] 1.10[c]	0.95
Medium voltage >1 kV to 35 kV (IEC 60038, table III)	1.10	1.00
High voltage[d] >35 kV (IEC 60038, table IV)		

a. $c_{max}U_n$ should not exceed the highest voltage U_m for equipment of power systems
b. For low-voltage systems with a tolerance of +6 %, for example systems renamed from 380 V to 400 V.
c. for low-voltage systems with a tolerance of +10 %
d. If no nominal voltage is defined $c_{max}U_n = U_m$ or $c_{min}U_n = 0.90 \times U_m$ should be applied.

Impedance Correction Factor:

$$K_T = 0.95\frac{c_{max}}{1 + 0.6x_T}$$

$$= 0.96328045$$

Transformer LV Impedance:

$$Z_T = \frac{u_{kr}}{100\%} \cdot \frac{U_{rT}^2}{S_{rT}}$$

$$Z_{TR-LV} = K_T \times 600 \times 600 \times 0.06/2000 \times 1000$$

$$= 0.010403429\Omega$$

$$R_T = \frac{u_{kr}}{100\%} \cdot \frac{U_{rT}^2}{S_{rT}} = \frac{P_{krT}}{3I_{rT}^2}$$

$$R_{TR-LV} = K_T \times \frac{\text{Losses kW}}{3(\text{Rated Current})^2}$$

$$= K_T \times \frac{19450}{3 \times (2000 \times 1000/600/1.73)^2}$$

$$= 0.001686124\Omega$$

$$X_T = \sqrt{Z_T^2 - R_T^2}$$

$$X_{TR-LV} = K_T \times \sqrt{Z^2 - R^2}$$

$$= 0.010265881\Omega$$

Fault Level on AC Re-combiner's Bus Bar

Using the above values in the formulae for the bus-bar fault level calculation, we can calculate the fault level on the AC re-combiner's bus bar as follows.

$$= \text{Voltage} \times \text{Voltage correction factor C/Fault Impedance}$$

$$= \frac{600 \times 1,05}{(Z_{TR-LV} + Z_{GRID}) \times \sqrt{3} \times 1000}$$

$$= \frac{600 \times 1,05}{\{(R_{TR-LV} + R_{LV-GRID})^2 + (X_{TR-LV} + X_{LV-GRID})^2\}^{1/2} \times \sqrt{3} \times 1000}$$

$$= \frac{600 \times 1,05}{\{(0,001765224)^2 + (0,011053921)^2\}^{1/2} \times \sqrt{3} \times 1000}$$

$$= 32.494\text{kA}$$

Selection of incomer circuit breaker, bus-bar and outgoing circuit breaker shall be based on this fault level calculation and nominal rated current.

If 125kW rating is used (for UPF operation):

For a 2 MVA block, with 16 Conext CL125E Inverters, 4 AC combiner boxes combining 4 inverters each, the AC re-combiner box will have 4 incomers, each with 630A nominal current and respective fault level.

The length of cables between AC re-combiner and transformer (being very short) doesn't make much difference to the selection of the circuit breaker's fault level. Transformer impedance and grid short-circuit fault level makes a small difference but is not significant. The major difference comes from the size of the transformer and LV voltage level. Designers should consider this when designing the system.

Figure 4-6 provide an example for understanding the dependency of circuit breaker selection on the bus-bar fault level, as well as the dependency of the bus-bar fault level in the selection of components.

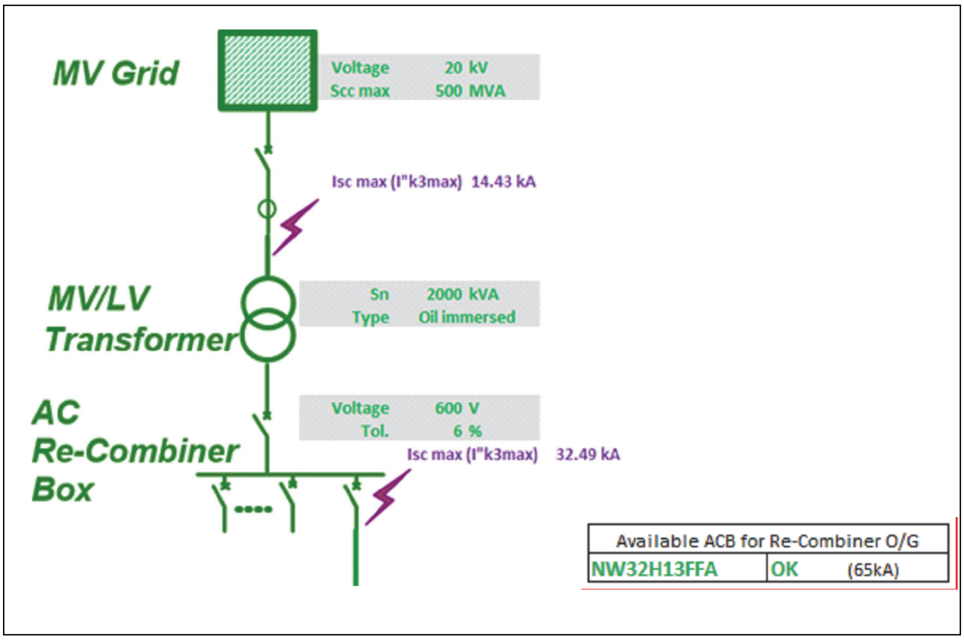


Figure 4-6 Breaker selection with 2000 kVA transformer

Recommended Circuit Breaker for AC Re-combiner Incoming

We recommend using Compact NSX630R type breakers for the AC re-combiner incomer to have up to 45kA fault current capacity at 660VAC at 50Hz.

Product name	Compact NSX
Product short name	NSX630R - 630 A
Poles description	3P
Network frequency	50/60 Hz
Suitability for isolation	Yes
Utilization category	Category A
Trip unit technology	Thermal-magnetic
Breaking capacity	45 kA at 660/690VAC

Recommended Circuit Breaker for AC Re-combiner Outgoing

Outgoing current of AC re-combiner:

$$= \text{Block kVA size} \times 1000 / \sqrt{3} \times \text{Voltage}$$
$$= 2000 \times 1000 / 1,732 \times 600$$
$$= 1925\text{A}$$

Expected fault level ~ 50kA

With the above specification, the recommended circuit breaker is Masterpact NW25H1 – 2500A – 3 pole (fixed or withdrawable) – with Micrologic trip unit.

Device short name	Masterpact NW25
Poles description	3P
Network type	AC
Suitability for isolation	Yes
Utilization category	Category B
Network frequency	50/60 Hz
Control type	Push button
Mounting mode	Fixed
[I_n] rated current	2500 A (40°C)
[U_i] rated insulation voltage	1000
[U_{imp}] rated impulse withstand voltage	12 kV
[I_{cm}] rated short-circuit making capacity	143 kA
[U_e] rated operational voltage	690 V
Circuit breaker CT rating	2500 A
Breaking capacity	65 kA

Circuit Breaker Protection - Discrimination Table for Selection

To achieve the correct level of discrimination and cascading between selected circuit breakers, use the following tables. If the installed circuit breakers have different combinations, check the “Complementary Technical Information”: Low voltage catalogue for more discrimination tables.

Complementary technical information

Ue ≤ 440 V

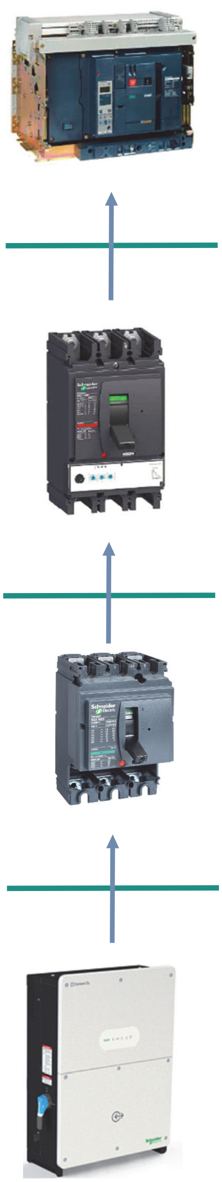
Discrimination table

Upstream: Compact NSX400-630 Micrologic

Downstream: iDPN, iC60, C120, NG125-160, Compact NSX100-400

Upstream		NSX400F/N/H/S/L/R					NSX630F/N/H/S/L/R				
Trip unit		Micrologic					Micrologic				
Downstream	Rating (A)	400					630				
	Setting Ir	160	200	250	320	400	250	320	400	500	630
Discrimination limit (kA)											
IDPN		T	T	T	T	T	T	T	T	T	T
IDPNN		T	T	T	T	T	T	T	T	T	T
IC60N/H/L		T	T	T	T	T	T	T	T	T	T
Discrimination limit (kA)											
C120N/H	≤ 80	T	T	T	T	T	T	T	T	T	T
	100		T	T	T	T	T	T	T	T	T
	125			T	T	T	T	T	T	T	T
Discrimination limit (kA)											
NG125N/H/L	≤ 80	T	T	T	T	T	T	T	T	T	T
	100		T	T	T	T	T	T	T	T	T
	125			T	T	T	T	T	T	T	T
Discrimination limit (kA)											
NG160E/N/H	≤ 80	T	T	T	T	T	T	T	T	T	T
	100	T	T	T	T	T	T	T	T	T	T
	125		T	T	T	T	T	T	T	T	T
	160			T	T	T	T	T	T	T	T
Discrimination limit (kA)											
Compact NSX100 B/F/N/H/S/L/R TM-D	≤ 80	T	T	T	T	T	T	T	T	T	T
	100	T	T	T	T	T	T	T	T	T	T
Discrimination limit (kA)											
Compact NSX160 B/F/N/H/S/L TM-D	≤ 100	T	T	T	T	T	T	T	T	T	T
	125		T	T	T	T	T	T	T	T	T
	160			T	T	T	T	T	T	T	T
Discrimination limit (kA)											
Compact NSX250 B/F/N/H/S/L/R TM-D	≤ 100	4.8	4.8	4.8	4.8	4.8	T	T	T	T	T
	125		4.8	4.8	4.8	4.8	T	T	T	T	T
	160			4.8	4.8	4.8	T	T	T	T	T
	200				4.8	4.8		T	T	T	T
	250					4.8			T	T	T
Discrimination limit (kA)											
Compact NSX100 B/F/N/H/S/L/R Micrologic	40	T	T	T	T	T	T	T	T	T	T
	100	T	T	T	T	T	T	T	T	T	T
Discrimination limit (kA)											
Compact NSX160 B/F/N/H/S/L Micrologic	40	T	T	T	T	T	T	T	T	T	T
	100	T	T	T	T	T	T	T	T	T	T
	160			T	T	T	T	T	T	T	T
Discrimination limit (kA)											
Compact NSX250 B/F/N/H/S/L/R Micrologic	≤ 100	4.8	4.8	4.8	4.8	4.8	T	T	T	T	T
	160			4.8	4.8	4.8	T	T	T	T	T
	250					4.8			T	T	T
Discrimination limit (kA)											
Compact NSX400 F/N/H/S/L/R Micrologic	160						6.9	6.9	6.9	6.9	6.9
	200							6.9	6.9	6.9	6.9
	250								6.9	6.9	6.9
	320									6.9	6.9
	400										6.9

4	*Discrimination limit = 4 kA.*
T	*Total discrimination, up to the breaking capacity of the downstream circuit breaker.*
	No discrimination.



Complementary technical information

Ue ≤ 440 V

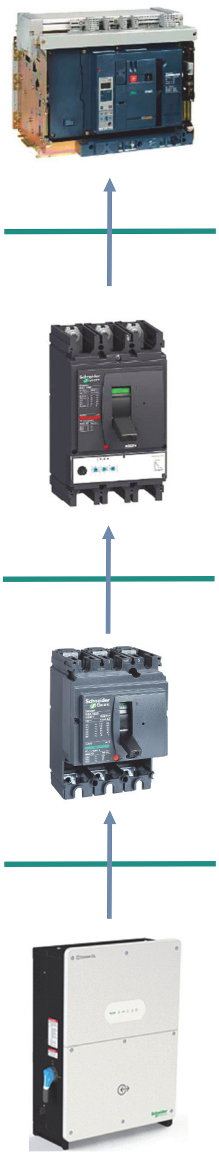
Protection discrimination

Upstream: Masterpact NW08-20 N1/H1/H2/L1 Micrologic
Downstream: iDPN, iC60, C120, NG125-160, Compact NSX100-630

Upstream		Masterpact NW08/12/16/20 N1/H1/H2/L1																				
Trip unit		Micrologic 2.0							Micrologic 5.0 - 6.0 - 7.0 Inst : 15 In							Micrologic 5.0 - 6.0 - 7.0 Inst : OFF						
Downstream	Rating (A)	800			1000	1250	1600	2000	800			1000	1250	1600	2000	800			1000	1250	1600	2000
	Setting Ir	320	630	800	1000	1250	1600	2000	320	630	800	1000	1250	1600	2000	320	630	800	1000	1250	1600	2000
Discrimination limit (kA)																						
iDPN, iDPNN		T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
iC60		T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
C120N/H		T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
NG125N/H		T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
NG125L		T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
NG160E/N/H		T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
Compact NSX100 B/F/N/H/S/L/R TM-D		T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
Compact NSX160 B/F/N/H/S/L TM-D		T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
Compact NSX250 B/F/N/H/S/L/R TM-D	≤ 125	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	160	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	200	T	T	T	T	T	T	T		T	T	T	T	T	T		T	T	T	T	T	T
	250		T	T	T	T	T	T		T	T	T	T	T	T		T	T	T	T	T	T
Compact NSX100 B/F/N/H/S/L/R Micrologic	40	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	100	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
Compact NSX160 B/F/N/H/S/L Micrologic	40	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	100	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	160	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
Compact NSX250 B/F/N/H/S/L/R Micrologic	≤ 100	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	160	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	250		T	T	T	T	T	T	T	T	T	T	T	T	T		T	T	T	T	T	T
Compact NSX400 F/N/H/S/L/R Micrologic	160	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	200	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	250	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	320		T	T	T	T	T	T		T	T	T	T	T	T		T	T	T	T	T	T
	400		T	T	T	T	T	T		T	T	T	T	T	T		T	T	T	T	T	T
Compact NSX630 F/N/H/S/L/R Micrologic	250	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	320		T	T	T	T	T	T		T	T	T	T	T	T		T	T	T	T	T	T
	400		T	T	T	T	T	T		T	T	T	T	T	T		T	T	T	T	T	T
	500			T	T	T	T	T			T	T	T	T	T			T	T	T	T	T
	630				T	T	T	T				T	T	T	T				T	T	T	T

T — *Total discrimination, up to the breaking capacity of the downstream circuit breaker.*

(blank) — *No discrimination.*



Complementary technical information

Ue ≤ 440 V

Protection discrimination

Upstream: Masterpact NW25-40 H1/H2, Masterpact NW40b-63 H1 Micrologic
Downstream: iDPN, iC60, C120, NG125-160, Compact NSX100-630, NS630b-3200

Upstream		Masterpact NW25/32/40 H1/H2			Masterpact NW40b 50/63 H1			Masterpact NW25/32/40 H1/H2			Masterpact NW40b 50/6 3H1			Masterpact NW25/32/40 H1/H2			Masterpact NW40b 50/63 H1		
Trip unit		Micrologic 2.0						Micrologic 5.0 - 6.0 - 7.0 Inst : 15 In						Micrologic 5.0 - 6.0 - 7.0 Inst : OFF					
Downstream	Rating (A)	2500	3200	4000	4000	5000	6300	2500	3200	4000	4000	5000	6300	2500	3200	4000	4000	5000	6300
Discrimination limit (kA)																			
iDPN, iDPNN		T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
iC60		T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
C120N/H		T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
NG125N/H/L		T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
NG160E/N/H		T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
Compact NSX B/F/H/N/S/L/R TM-D	NSX100	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	NSX250	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
Compact NSX160 B/F/H/N/S/L TM-D		T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
Compact NSX B/F/H/N/S/L/R Micrologic	NSX100	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	NSX250	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
F/H/N/S/L/R Micrologic	NSX400	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	NSX630	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
Compact NSX160 B/F/H/N/S/L Micrologic		T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
Compact NS N Micrologic	NS630b	25	32	40	40	T	T	37.5	48	T	T	T	T	T	T	T	T	T	T
	NS800	25	32	40	40	T	T	37.5	48	T	T	T	T	T	T	T	T	T	T
	NS1000	25	32	40	40	T	T	37.5	48	T	T	T	T	T	T	T	T	T	T
	NS1250	25	32	40	40	T	T	37.5	48	T	T	T	T	T	T	T	T	T	T
	NS1600	25	32	40	40	T	T	37.5	48	T	T	T	T	T	T	T	T	T	T
Compact NS H Micrologic	NS630b	25	32	40	40	50	63	37.5	48	60	60	T	T	T	T	T	T	T	T
	NS800	25	32	40	40	50	63	37.5	48	60	60	T	T	T	T	T	T	T	T
	NS1000	25	32	40	40	50	63	37.5	48	60	60	T	T	T	T	T	T	T	T
	NS1250	25	32	40	40	50	63	37.5	48	60	60	T	T	T	T	T	T	T	T
	NS1600	25	32	40	40	50	63	37.5	48	60	60	T	T	T	T	T	T	T	T
Compact NS N Micrologic	NS1600b	25	32	40	40	50	63	37.5	48	60	60	T	T	T	T	T	T	T	T
	NS2000	25	32	40	40	50	63	37.5	48	60	60	T	T	T	T	T	T	T	T
	NS2500	25 (1)	32	40	40	50	63	37,5 (1)	48	60	60	T	T	T (1)	T	T	T	T	T
	NS3200		32 (1)	40	40	50	63		48 (1)	60	60	T	T		T (1)	T	T	T	T
Compact NS H Micrologic	NS1600b	25	32	40	40	50	63	37,5	48	60	60	75	T	T	T	T	T	T	T
	NS2000	25	32	40	40	50	63	37,5	48	60	60	75	T	T	T	T	T	T	T
	NS2500	25 (1)	32	40	40	50	63	37,5 (1)	48	60	60	75	T	T (1)	T	T	T	T	T
	NS3200		32 (1)	40	40	50	63		48 (1)	60	60	75	T		T (1)	T	T	T	T
Compact NS L Micrologic	NS630b	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	NS800	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	NS1000	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
Compact NS LB Micrologic	NS630b	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	NS800	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T

(1) With Ir upstream > 1, 3 Ir downstream.

T	*Total discrimination, up to the breaking capacity of the downstream circuit breaker.*
4	*Discrimination limit = 4 kA.*
	No discrimination.

5 Important Aspects of a Decentralized System Design

This chapter on the aspects of a decentralized system design contains the following information:

- Grounding System Design for Decentralized PV systems
- Grid Connection
- Role of Circuit Impedance in Parallel Operation of Multiple Conext CL String Inverters

Selection of Residual Current Monitoring Device (RCD)

⚠ DANGER

RISK OF FIRE, ELECTRIC SHOCK, EXPLOSION, AND ARC FLASH

RCD must be selected by qualified persons. The failure of an RCD can cause damage to the inverter, the system, or both. It may also cause personal injury upon contact during the fault.

Failure to follow these instructions will result in death or serious injury.

“Residual current” refers to the leakage current from an electrical system to the ground, often as a result of a “ground fault”. Leakage currents can flow through a human body to ground resulting in a risk of electric shock, injury or burns, and can cause overheating and risk of fire. A Residual Current Device (RCD) is used to detect these currents and disconnect the circuit from the source automatically when the values of these residual currents exceed the predefined limits.

A Residual Current Monitoring Unit (RCMU) is similar to an RCD except it does not contain the disconnection function and can only activate an alarm. The residual current may be a pure alternating current (AC), a pure direct current (DC), or a current with both AC and DC components. The proper functioning of an RCD or RCMU is only ensured if the type of RCD or RCMU is matched to the type of residual current expected: AC, DC, or mixed.

In some jurisdictions, RCD’s are required to be installed on AC circuits in which photovoltaic (PV) inverters are connected. In a grid-tied PV system with a non-isolated inverter, it is possible for a ground fault on the PV system to cause DC residual current in the AC part of the system. Therefore, if an RCD is required on the AC circuit, its proper selection requires awareness of the properties of the inverter. Many inverters contain RCD or RCMU functions to protect against or warn of ground faults in the PV array, and of the limitations of such PV residual current functions.

The IEC 60755 standard specifies the following three types of RCDs, which are defined by their ability to sense, properly trip, and withstand different types of current:

- Type AC – sensitive to residual sinusoidal alternating current (AC).
- Type A – sensitive to residual sinusoidal alternating current (AC) or pulsed direct current (DC).
- Type B – sensitive to residual AC, pulsed DC, or smooth DC currents.

Only Type B RCDs are able to withstand and properly function in the presence of a DC residual current component exceeding 6 mA. These different types of RCDs are marked with specific symbols, as defined in IEC 60755

The white paper, “Guidance on Proper Residual Current Device Selection for Solar Inverters” by K. Ajith Kumar and Jim Eichner, provides more guidance on the requirement and selection of RCDs.

The Conext CL125 Inverter has a built-in RCMU. This continuous RCD is set at <1250mA (or higher for larger systems) and a sudden change detector with limits as listed in the following table (based on DIN/VDE 0126-1-1, EN/IEC 62109-2, and other standards):

Residual current sudden change	Maximum time to inverter disconnection from the mains
30 mA	300 ms
60 mA	150 ms
150 mA	40 ms

Selection of a Surge Protection device for Decentralized PV systems

⚠ DANGER

ELECTRICAL SHOCK AND FIRE HAZARD

Installation including wiring must be done by qualified personnel to ensure compliance with all applicable installation and electrical codes including relevant local, regional, and national regulations. Installation instructions are not covered in this Solution Guide but are included in the relevant product manuals for the Conext CL125 Inverter. Those instructions are provided for use by qualified installers only.

Failure to follow these instructions will result in death or serious injury.

Surge arrestors protect the electrical wiring, components and system from lightning surges. The role of the surge arrester is to drive the lightning current to the earth in a very short time (<350 microseconds). However, surge arrestors are not intended to be exposed to permanent over voltages. In that case, it might create a short circuit and may damage the switch board.

Surge protection selection points:

- The protection level of SPD must be lower than the impulse withstand voltage level of equipment protected by SPD
- For a TNC grounding scheme, 3P SPDs should be used
- For a TNS grounding scheme, 3P+N SPDs should be used.
- If the PV system is installed in the vicinity (within 50m) of a lightning protection rod or lightning termination, a Type 1 SPD will be required to safeguard the inverter from lightning discharge currents as It is used to conduct the direct lightning current, propagating from the earth conductor to the network conductors.
- Geographical conditions cause the specific level of Lightning Flash density. Based on the level of lightning flash density and commercial value of the equipment protected, the level of surge protection has to be decided and so is the fault level (kA) of SPD.
- After having chosen the surge protection device for the installation, the appropriate disconnection circuit breaker is to be chosen from the opposite table. Its breaking capacity must be compatible with the installation's breaking capacity and each live conductor must be protected, e.g., 3P SPD must be combined with a 3P MCCB.

Use of SPDs on DC circuits

DC type surge protection devices should be installed in a switchboard inside the building. If the switchboard is located outside, it must be weatherproof. Withdrawable DC surge arresters allow damaged cartridges to be replaced quickly.

The surge arrester base can be turned over to allow the phase/earth cables to enter through either the top or the bottom. They offer remote reporting of the "cartridge must be changed" message.

Depending on the distance between the "generator" part and the "conversion" part, it may be necessary to install two surge arresters or more, to ensure protection of each of the two parts.

Calculation for DC surge protection:

To protect the inverter you need to have Protection level Up (surge arrester) $< 0.8\ Uw$ (inverter)

If the distance between the module and inverter > 10m, a second surge protection should be installed close to the module except if $Up < 0.5\ Uw$ (module)

Uw is the impulse withstand.

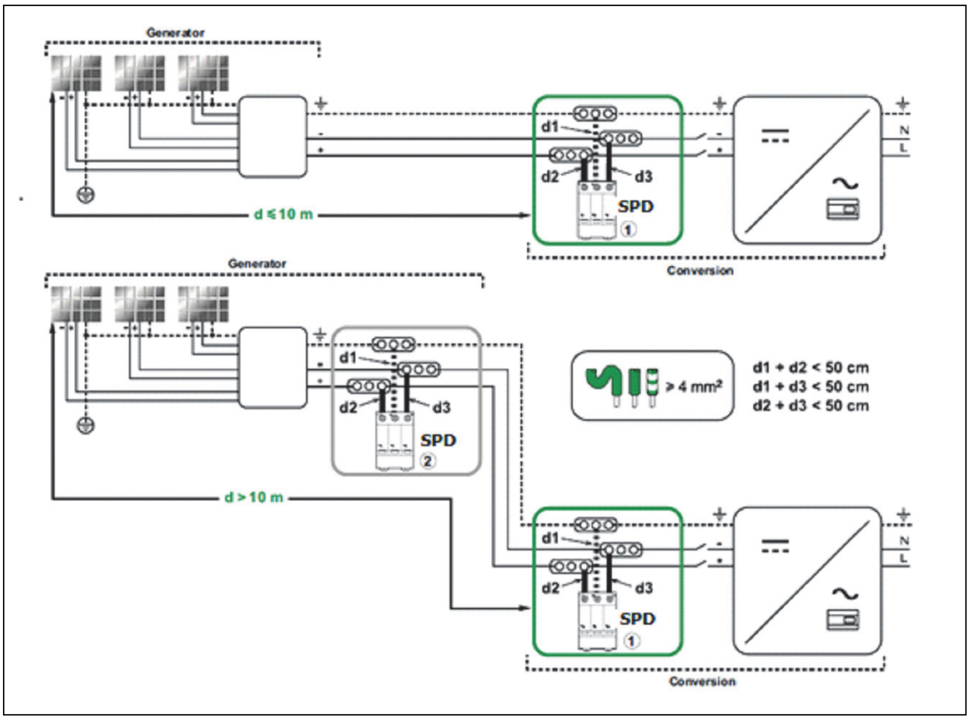
The CL125E is category II so, its $Uw = 6kV$.

The 1500V modules are usually cat A so their $Uw = 8kV$.

To protect the inverter from Surge SPD should be less than $0.8 \times 6 = 4.8kV$

To avoid additional SPD for PV modules rating of SPD should be $< 0.5 \times 8 = 4kV$

The following diagram indicates the additional SPD requirement considering that the impulse withstand voltage of the PV module is lesser than Up of SPD inside the CL125E inverter.



The following use case provides an example to understand the installation of SPDs:

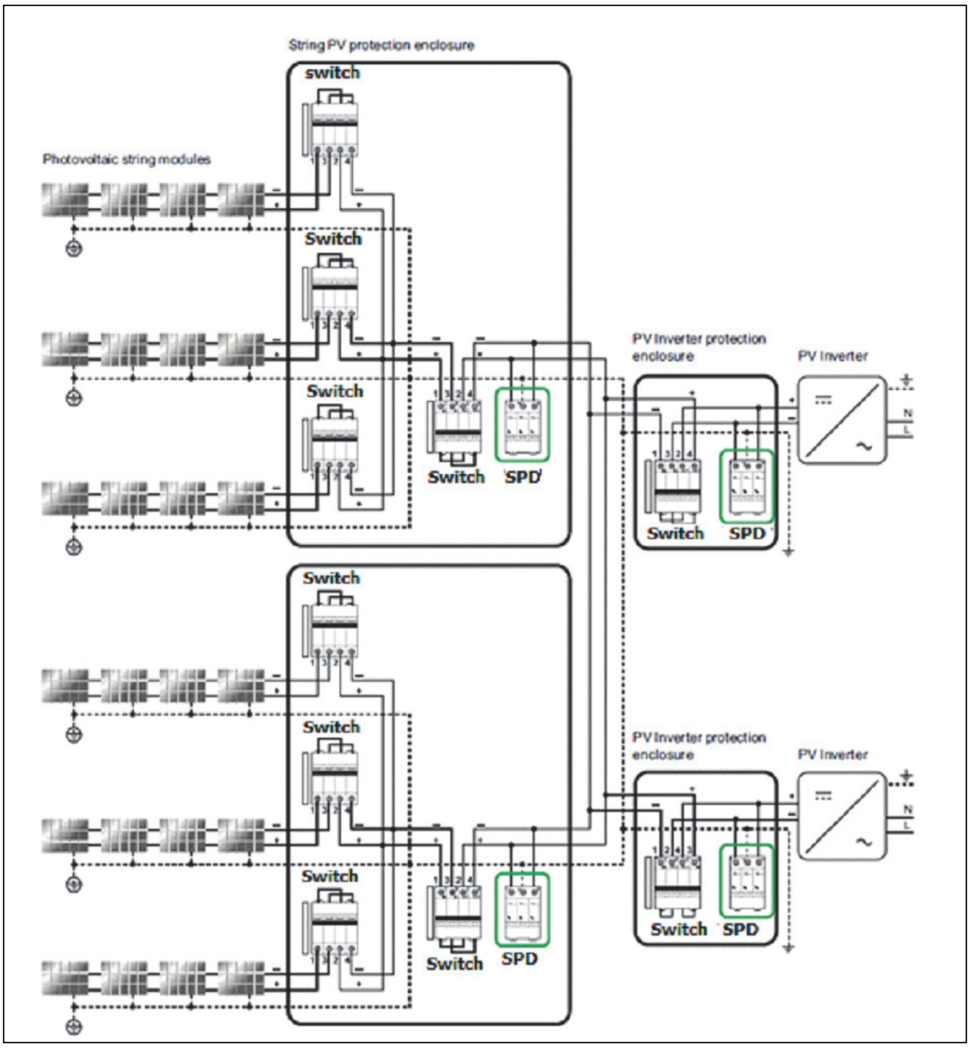


Figure 5-1 Installation of SPDs

In the case of PV architecture without an earthed polarity on the DC side and with a PV inverter or with galvanic isolation, it is necessary to:

- protect each string of photovoltaic modules with a suitably rated DC switch installed in the junction box near the PV modules;
- add an insulation monitoring device on the DC side of the PV inverter in order to indicate first earth fault and actuate stoppage of inverter as soon as it occurs.

Restarting will be possible only after eliminating the fault.

Schneider Electric has certified coordination between the surge arrester and its disconnection circuit breaker (IEC 61643-11 2005 version). The following diagram indicates the possible coordination with Type 2 SPDs.

For the installations with a lightning rod within 50m of the area, Type 1 SPDs to be used with disconnecting devices.

Use of SPD on AC Circuits in Decentralized PV systems

The CL125E inverter has a built-in Type 2 SPD on the output AC circuit (as indicated in the wiring diagram). This Type 2 SPD device is mainly to protect the inverter.

To protect the AC output circuit, it is important to select the correct size of Type 2 SPD.

- If the AC cable length is >30m, it will require cascading of SPD for downstream protection.
- This AC SPD provides type 2 protection to the Inverter from AC system surges from grid. For the protection of AC Low voltage systems, we recommend selecting the respective type of SPD based on the country code and the area lightning protection requirements.
- We recommend using suitable circuit disconnecting means with an SPD device inside or outside the inverter wiring box.
- The Type 2 PCB mounted surge protection provided inside the CL125E wiring box is not meant to protect AC LV grid components.
- For an effective surge protection, shorten the length of cables. Lightning is a phenomenon that generates high frequency voltage. 1 m length of cable crossed by a lightning current generates approximate over voltage in the order of 1000V.
- In practice, consider intermediate grounding terminals inside the switch boards to shorten the cable lengths. IEC 60364-5-534 mandates to restrict the overall length of cables (connected to SPD and terminating to ground) up to 50cm.

Figure 5-2 shows the circuit of internal SPD connections of Conext CL wiring box.

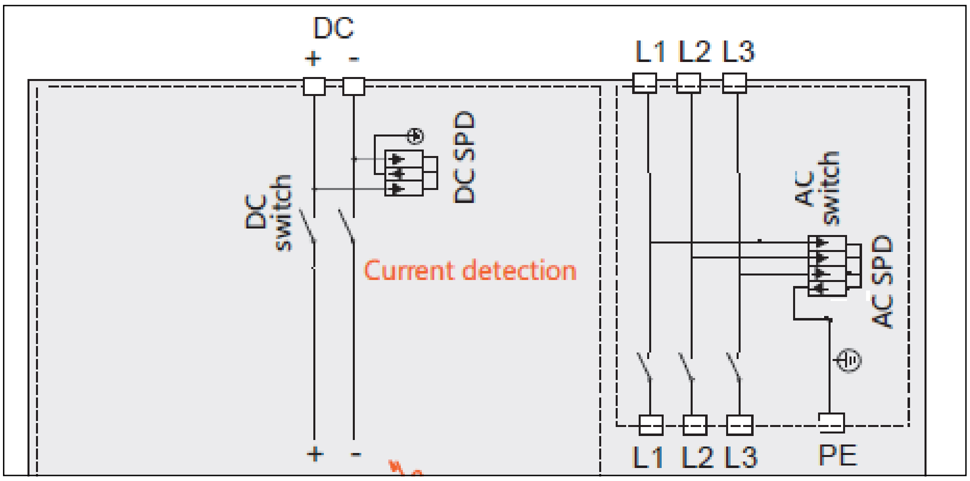


Figure 5-2 Circuit of Internal SPD Connections

In 3 phase AC LV systems, surge protection also depends on the type of grounding system that is followed for the wiring of 3 phases and neutral. Figure 5-3, Figure 5-4, and Figure 5-5 show examples that illustrate the connection of SPDs in AC LV circuits.

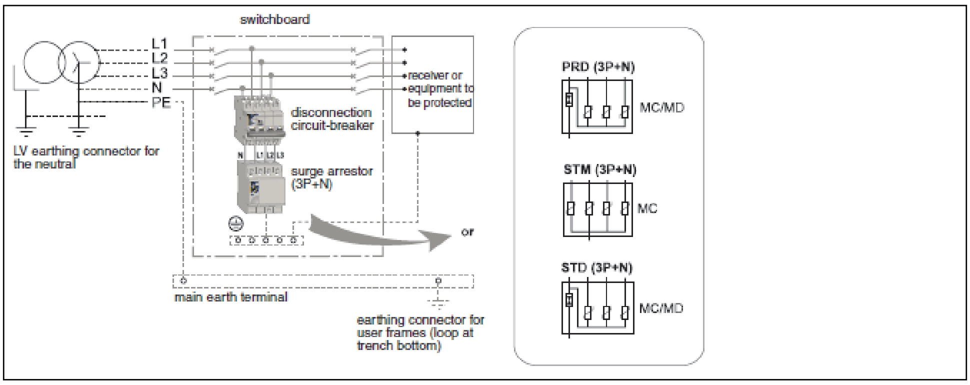


Figure 5-3 TN-S Earthing System, 3-Phase + Neutral

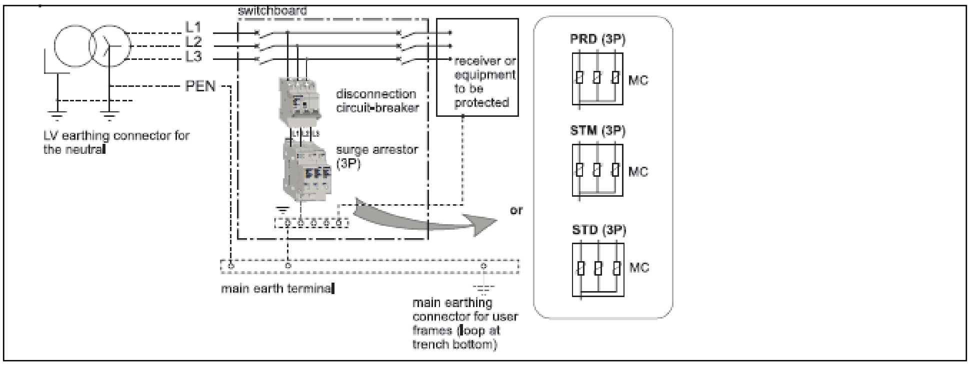


Figure 5-4 TN-C Earthing System, 3-Phase

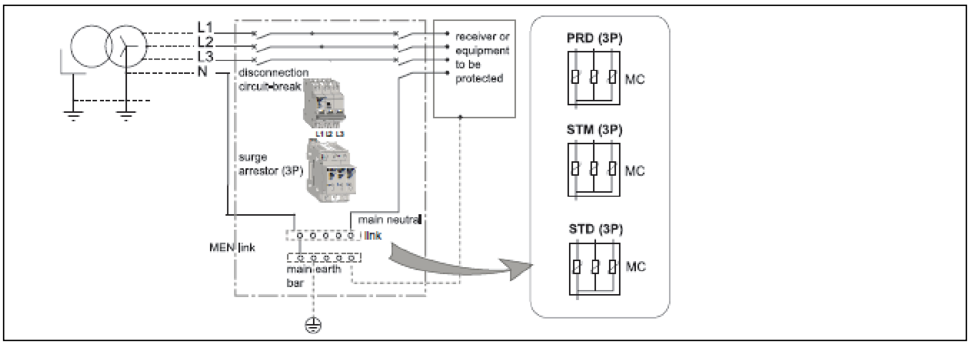


Figure 5-5 MEN Earthing System, 3-Phase

Grounding System Design for Decentralized PV systems

General Understanding of Grounding

The different grounding schemes (often referred to as the type of power system or system grounding arrangements) described characterize the method of grounding the installation downstream of the secondary winding of a MV/LV transformer and the means used for grounding the exposed conductive-parts of the LV installation supplied from it.

The choice of these methods governs the measures necessary for protection against indirect-contact hazards.

The grounding system qualifies three originally independent choices made by the designer of an electrical distribution system or installation:

- The type of connection of the electrical system (which is generally of the neutral conductor) and of the exposed parts to earth electrode(s)
- A separate protective conductor or protective conductor and neutral conductor being a single conductor
- The use of earth fault protection of overcurrent protective switchgear which clears only relatively high fault currents or the use of additional relays able to detect and clear small insulation fault currents to earth

In practice, these choices have been grouped and standardized as explained below.

Each of these choices provides standardized grounding systems with three advantages and drawbacks:

- Connection of the exposed conductive parts of the equipment and of the neutral conductor to the PE conductor results in equi-potentiality and lower over voltages, but it increases earth fault currents.
- A separate protective conductor is costly even if it has a small cross-sectional area, but it is much more unlikely to be polluted by voltage drops and harmonics, etc. than a neutral conductor is. Leakage currents are also avoided in extraneous conductive parts.
- Installation of residual current protective relays or insulation monitoring devices are much more sensitive and, in many circumstances, are able to clear faults before heavy damage occurs (motors, fires, electrocution). The protection offered is also independent with respect to changes in an existing installation.

Grounding for PV Systems

PV systems are either insulated from the earth or one pole is earthed through an overcurrent protection. In both set-ups, therefore, there can be a ground fault in which current leaks to the ground. If this fault is not cleared, it may spread to the healthy pole and give rise to a hazardous situation where fire could break out. Even though double insulation makes such an eventuality unlikely, it deserves full attention.

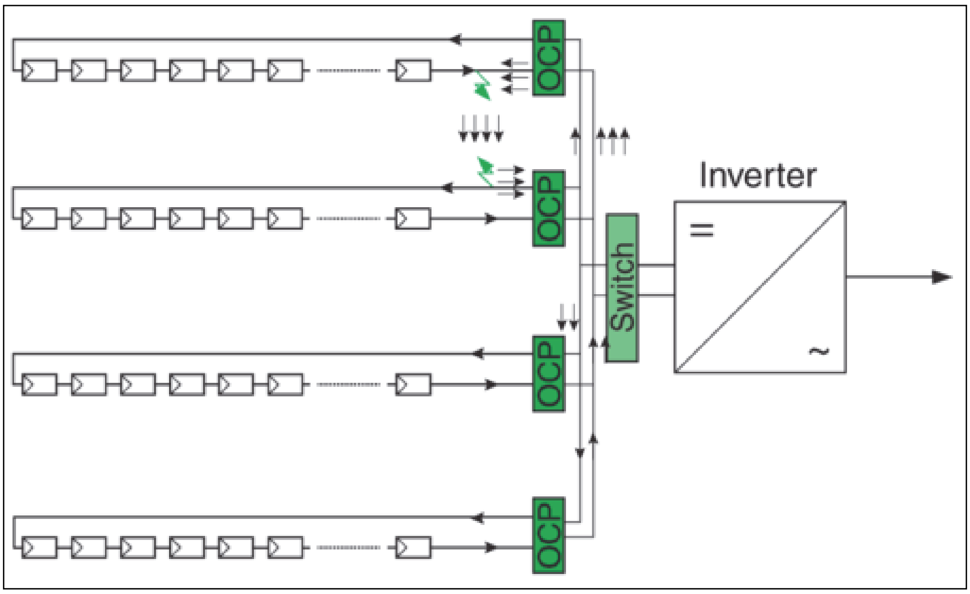


Figure 5-6 Reverse Current

Insulation monitoring devices or overcurrent protection in earthed systems shall detect the first fault and staff shall look after the first fault and clear it with no delay.

For the following two reasons, the double fault situation shall be absolutely avoided:

- The fault level could be low (e.g., two insulation faults or a low short-circuit capability of the generator in weak sunlight) and below the tripping value of the overcurrent protection (circuit breaker or fuses). However, a DC arc fault does not spend itself, even when the current is low. It could be a serious hazard, particularly for PV modules on buildings.
- Circuit breakers and switches used in PV systems are designed to break the rated current or fault current with all poles at open-circuit maximum voltage (UOC MAX). To break the current when UOC MAX is equal to 1500V. In double ground fault situations, the circuit breaker or switches must break the current at full voltage with only two poles in series. Such switchgear is not designed for that purpose and could sustain irremediable damage if used to break the current in a double-ground fault situation.

The ideal solution is to prevent double ground faults from arising. Insulation monitoring devices or overcurrent protection in grounded systems detects the first fault. However, although the insulation fault monitoring system usually stops the inverter, the fault is still present. Staff must locate and clear it without delay. In large generators with sub arrays protected by circuit breakers, it is highly advisable to disconnect each array when that first fault has been detected but not cleared within the next few hours.

Example of grounding circuit connections for a decentralized PV design.

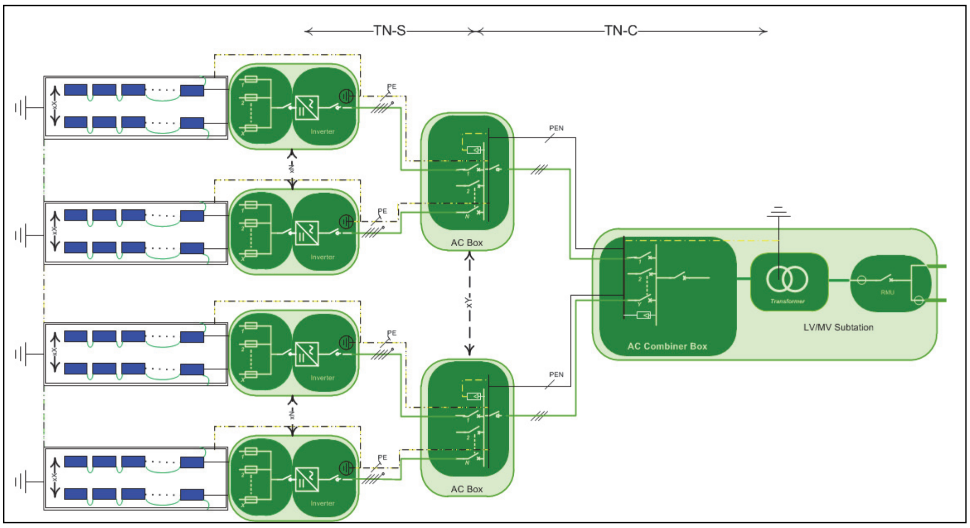


Figure 5-7 Grounding Circuit Connections

Sizing of the grounding conductor should be followed by country and area installation codes for grounding PV systems. Selection of system components like SPDs, MCCB and MCB, Disconnect switches, Panel enclosures and cables should be in accordance with the type of grounding system followed by the utility and installed type of transformer. Typical practices followed by local area safety council and fire-fighting departments should be taken into consideration when designing the PV system grounding scheme.

Transformer selection for decentralized PV plants with Conext CL

Transformers for PV application are designed with respect to the size of AC block. We recommend multiplication of 2500kVA block for large MW scale plants. For smaller residential or commercial plants that need to connect to the Utility POC at medium voltage level, transformers can be ranged anywhere between 250kW to 2600kW.

Some features a transformer for PV system could be,

- A shield winding is recommended as a dU/dt filter between the low voltage and high voltage windings.
- LV-MV impedance Z (%) for the transformer must be within 5% to 6%; nominally 6%. In the case of multiple LV windings, Z (%) refers to a simultaneous short circuit on all LV terminals.
- The configuration of the MV transformer should take into account the local grid frequency and should meet local and regional standards.
- For multiple Inverters connected on one transformer secondary winding, the low voltage (inverter-side) windings of the MV transformer can only be configured as Dy11 or Dy0. If the MV side of the system is grounded Wye, use of a floating Wye on the inverter side may not be allowed by the local utility. Make sure you understand your system configuration and the utility's rules before installation.

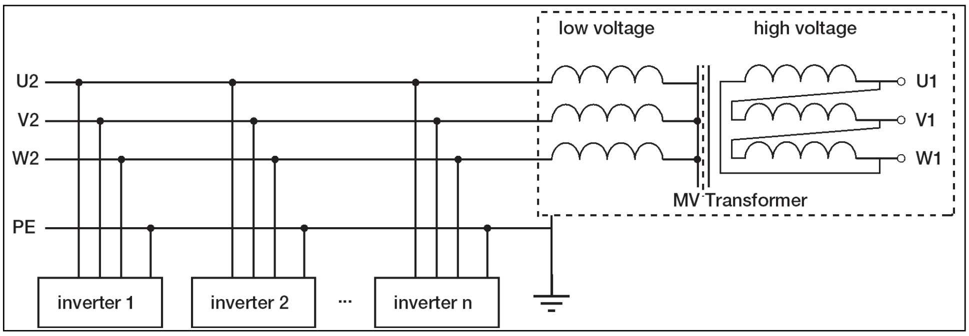


Figure 5-8 Parallel connection of multiple inverters to transformer winding

The following standard sizes of transformers are listed under IEC and the table indicates generalized power loss values for transformer ratings and impedance. (According to EU regulation 548/2014 – Ecodesign)

Table 5-1 Power loss values for transformer ratings and impedance[a]

		Load losses (Copper)				No load losses (Iron)				
Ucc	Sn	Dk	Ck	Bk	Ak	E0	D0	C0	B0	A0
4%	250 kVA	4200 W	3250 W	2750 W	2350 W	650 W	530 W	425 W	360 W	300 W
	500 kVA	7200 W	5500 W	4600 W	3900 W	1100 W	880 W	720 W	610 W	510 W
6%	1000 kVA	13000 W	10500 W	9000 W	7600 W	1700 W	1400 W	1100 W	940 W	770 W
	1250 kVA	16000 W	13500 W	11000 W	9500 W	2100 W	1750 W	1350 W	1150 W	950 W
	2000 kVA	26000 W	21000 W	18000 W	15000 W	3100 W	2700 W	2100 W	1800 W	1450 W
	2500 kVA	32000 W	26500 W	22000 W	18500 W	3500 W	3200 W	2500 W	2150 W	1750 W

a.According to EU regulation 548/2014 – Ecodesign

For multi MW PV systems, we recommend to parallel a maximum of 40 Conext CL inverters to each LV winding of transformer. Lower impedance and a slightly oversized (up to 10%) transformer would support smooth parallel operation of inverters. It's recommended to use the standards size of transformer available on the market to avoid long manufacturing time and higher market prices.

Schneider Electric offers a Minera PV type high-efficiency oil-immersed transformer for photovoltaic systems up to 1250kVA and 36kV, 50/60 Hz.

Monitoring System Design

Conext CL125 Inverters offer the option to connect over Modbus RS485 or Ethernet. Two ports (RJ45) for each Modbus RTU and Modbus TCP are provided. Any third-party data logger could be configured to connect with the Inverter and use the data logged by the Inverter to display over a monitoring portal. Conext CL125 Inverters offer standard Sunspec Modbus protocol for connectivity with third-party devices.

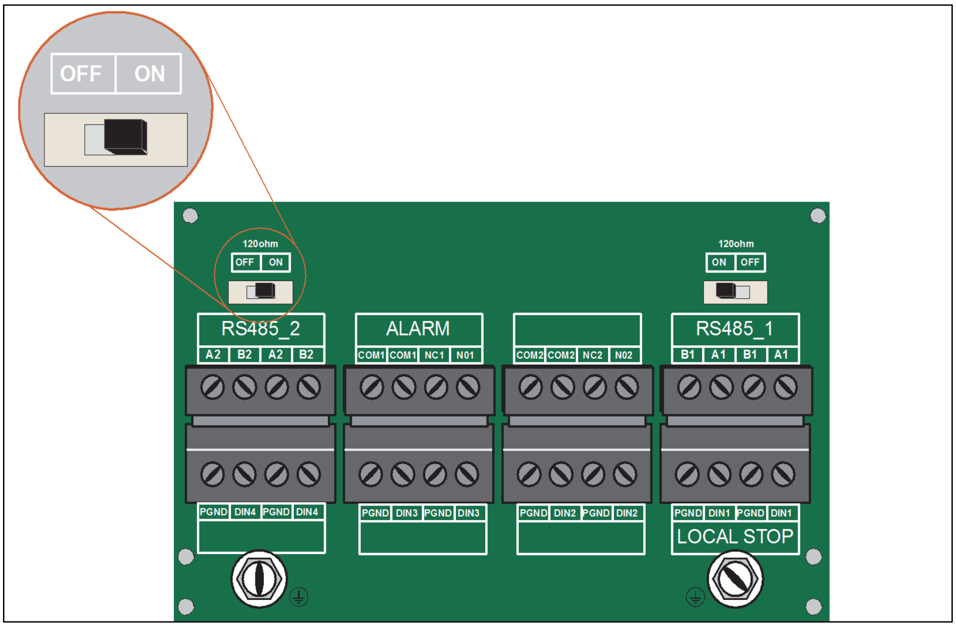


Figure 5-9 CL125E communication port and termination resistor details

For designing the communication architecture, we recommend keeping the length of Modbus RS485 loop within 1000m (length from monitoring data-logger to the last inverter).

Generally, third-party data-loggers specify the limits of the total number of inverters connected over a daisy chain (mostly up to 32), but this is an important parameter to know while designing the communication circuit for Conext CL125 Inverters.

Third-party monitoring solutions such as Solar-Log™, Also Energy, and Enerwise™ are pre-tested and qualified for plug and play.

For more information visit:

Solar-Log: www.solar-log.com
Also Energy: www.alsoenergy.com
Enerwise: www.enerwise.asia

Grid Connection

The connection of the PV plant to the utility grid terminates at the point of common coupling (PCC). Schneider Electric provides a Grid Box solution for achieving utility requirements at the PCC. Generally, Grid box mostly consists of the following components:

- An MV switchgear of rated grid voltage, current and fault current breaking capacity
- Tariff metering for Utility and Check Metering for PV plant owner
- PV plant controller
- A supervisory, Control and Data Acquisition system for the PV plant (if required by either the utility or the client)
- PV plant service transformer
- AC power distribution box
- Communication center for SCADA systems and PV plant security (optional)
- Main weather station of PV plant

Depending on the equipment and system, the size and quantity of the Grid box could change.

Along with basic monitoring capability, Schneider Electric offers advanced, state-of-the-art PV plant SCADA systems with Conext control monitoring platform as requested by client.

Contact Schneider Electric for further information about configuring SCADA systems, PV plant communication and Grid controller offers.

Role of Circuit Impedance in Parallel Operation of Multiple Conext CL String Inverters

For smooth, reliable and continuous parallel operation of Conext CL string inverters, it is important to follow the following recommendations from Schneider Electric.

- Restrict the AC cable impedance up to 3% of U_n.
- Restrict the Transformer impedance (between LV and HV winding) up to 6%
- If a three winding transformer is used (HV-LV-LV) including above point, also maintain the short circuit impedance of minimum or greater than 10% between each LV winding.
- Oversize (by 10%) the transformer kVA capacity with respect to installed inverter kW capacity.
- The AC cable sizing calculation should also consider the reactive impedance of cables and not just resistive. Grid impedance is an important parameter for this consideration.
- Calculate the grid impedance at PCC before designing the overall PV plant circuit. Short circuit power should be least 8 times higher than the plant installed power: $S_{sc,pcc} > 8 \times S_{plant}$

6 Layout Optimization

This chapter on layout optimization contains the following information:

- Layout Design Rules

Layout Design Rules

⚠ DANGER

ELECTRICAL SHOCK AND FIRE HAZARD

Installation including wiring must be done by qualified personnel to ensure compliance with all applicable installation and electrical codes including relevant local, regional, and national regulations. Installation instructions are not covered in this Solution Guide but are included in the relevant product manuals for the Conext CL125 Inverter. Those instructions are provided for use by qualified installers only.

Failure to follow these instructions will result in death or serious injury.

As a recommendation, the following layouts can be used to design standard blocks using Conext CL125 Inverters.

- Selection of structural design should be based on the string length and number of strings connected to each inverter.
- Arrangement of Modules on PV racking should be decided in-line with length of string to reduce DC string cable route length.
- In case of single axis trackers, this requirement becomes more stringent from both inverters and tracker's perspective.
- Location of the inverter should be decided prior to defining the block size.
- Connection of strings to Inverter and use of DC array combiner will be dependent on location of string inverter.
- Location of the AC array combiner box and LV-MV station should be selected in line with block size, to divide blocks and reduce cable length from AC combiners to LV-MV station.
- In most cases, the standard defined block should be multiplied to avoid several wiring mistakes and shorten installation time.

7 Frequently Asked Questions (FAQ)

This chapter of FAQs contains answers to general questions that may arise when considering Conext CL125 Inverters in designing a power system.

Safety Information

⚠ DANGER

ELECTRICAL SHOCK AND FIRE HAZARD

Installation including wiring must be done by qualified personnel to ensure compliance with all applicable installation and electrical codes including relevant local, regional, and national regulations. Installation instructions are not covered in this Solution Guide but are included in the relevant product manuals for the Conext CL125 Inverter. Those instructions are provided for use by qualified installers only.

Failure to follow these instructions will result in death or serious injury.

Frequently Asked Questions

1. Can we install third party components inside the wiring compartment within the inverter?

   No. Components installed inside the wiring compartment within the inverter are tested in the factory before dispatch and hold warranty for the product. If any external component is installed inside the wiring box, that may void warranty.
2. What type of Transformer can be connected with Conext CL125 Inverters?

   Dy1 Dy11, Dd0 type transformers should be connected with Conext CL inverter. LV voltage of transformer should match the inverter's AC output voltage and MV voltage should match the grid connection voltage. CL125E Inverters can also connect to Delta type networks. Choose the transformer based on the utility network requirements
3. What is the solution if my AC cable size is higher than the terminal size of Conext CL inverter?

   An external AC terminal box has to be used in certain situations. This box will have input from the inverter with the maximum cable size the inverter terminal can fit (185mm^2). And, the output terminal of this AC box can have higher sized cables as required by design.
4. Do I need assistance from Schneider Electric for first installation of Conext CL inverters?

   No. For first installation, follow Schneider Electric's installation manual for the Conext CL inverter. Familiarize yourself with possible hazardous situations, follow recommended installation practices, and use a certified installer. In case of any difficulty, you can contact Schneider Electric for assistance.
5. Do I need to contact Schneider Electric at the time of designing PV system configuration for proposal?

   We recommend that Installers / Developers contact Schneider Electric when they start considering the use of Conext CL inverters. This way we can help you to design the most reliable and cost competitive solution with no technical surprises during installation.

6. How can I update the firmware version of Conext CL inverter?

   Conext CL inverter firmware is available at http://solar.schneider-electric.com/product/conext-cl-125-string-inverter/. You can download the latest firmware and upload it using the Conext CL EasyConfig Tool installed on your computer. Every time the Conext CL inverter is installed, the installer should use the latest firmware version available on the website.

7. Where can I find the Conext CL OND file for PVsyst simulation?

   You can find it at http://solar.schneider-electric.com/product/conext-cl-125-string-inverter/

8. Is there any tool from Schneider Electric to help my sizing the strings for my installation?

   No. The Schneider Electric Sales Application Engineers can help Schneider Electric clients to size correct strings. A third-party software, such as PVsyst could also be used to size strings.

9. Is measurement of power inside the Conext CL inverter good enough for tariff metering?

   Measurement of power inside the Conext CL inverter takes place with built-in sensors. Accuracy of current and voltage sensors within CL125E inverters measures within +/-1% accuracy. Generally, tariff metering has stringent requirements for accuracy and other compliance related to utility. Users must discuss this requirement in detail with the utility company.

10. Where can I find an Installation manual for Conext CL inverters?

    The Installation manual for the Conext CL inverter can be found at

    http://solar.schneider-electric.com/product/conext-cl-125-string-inverter/

11. What is the Schneider Electric customer care contact detail for technical support?

    Customer care contact details in your respective region are found at

    http://solar.schneider-electric.com/tech-support/

12. Does Schneider Electric provide Engineering, Procurement, Installation and Commissioning services for PV systems?

    Yes. Contact us for more details and discussion for our services.

13. Which other system components can Schneider Electric offer?

    Follow the chart provided under the topic “Building Blocks of a Decentralized PV System” on page 2–4 to check the offers from Schneider Electric.

14. What is the maximum oversizing that I can achieve for Conext CL inverters?

    We recommend 20% to 30% oversizing. It can be more depending on the climatic conditions. Maximum oversizing for the CL Inverter could be up to 50% (1.5 DC-AC ratio). If more than 50% oversizing is required, contact your local Sales Application Engineer for technical assessment of string sizing. In any case, the limits of short circuit current for the inverter should not be violated.

15. How is a choice of transformer affected by the inverter's operating capability?

    The inverter's operational capability depends on the Transformer in two ways:

    - Parallel operation of inverter: The inverter's parallel operation is a function of short circuit impedance (Z%) and the transformer is a circuit component with a very large impedance portion of the overall circuit. We recommend keeping the Impedance of the transformer as low as possible.
    - The Conext CL inverter supports 3 phase 3 wire WYE and 3 wire DELTA wiring schemes. When the Transformer is selected, it is important to match the Utility side winding requirement as per Point of connection and the Low voltage side winding requirement as per the inverter's operational compatibility.

16. What is the limit of power factor Conext CL inverters are capable of?

    The Conext CL can operate within 0.8 lead and 0.8 lag power factor limit.

17. Does the Conext CL inverter support LVRT requirement?

    Yes. It does. LVRT requirement is specified in the respective PV grid code of the country. Conext CL inverter firmware is programmed to follow the LVRT requirement (curve) during certification of each country. Contact us to know the list of countries Conext CL inverters are certified for.

18. Do I need to have PSS/E model of Conext CL inverter? Can Schneider Electric provide it?

    Yes. Schneider Electric can provide a generic or user defined CL125E Inverter PSSE model file. This requirement is generally requested by Utilities to include the model of your power plant into their power system. We recommend that clients discuss this type of requirement with the utility well ahead (during the system planning stage) and choose the correct wiring scheme and metering scheme. A billable PSSE model can be created based on client's request. If you have such a requirement, contact us for further discussion.

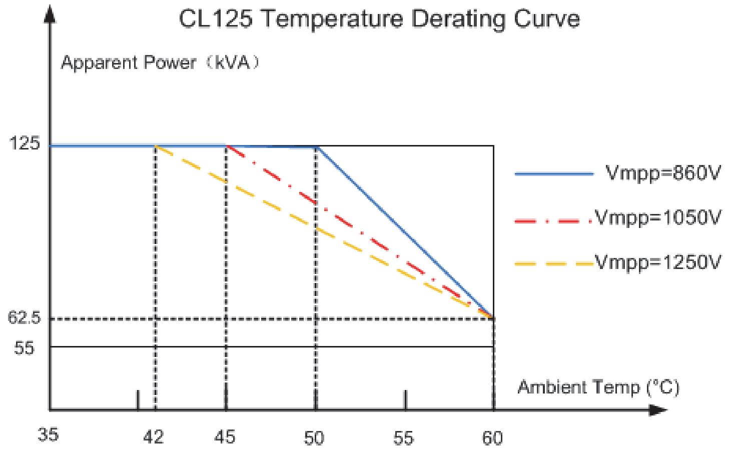
19. What type of support I can have from Schneider Electric for designing configuration of my PV system?

    Schneider Electric provides ready reference documentation for designing the system, for example, the Solutions guide, Owner's guide, training material, etc. If you need additional information or services, contact us for more discussion.

20. Which parameters do I have to confirm and use to order Conext CL inverters?

    Unlike centralized inverters, Conext CL string inverters are simple to configure and install. Since it is simple, there isn't any technical information sheet required to buy these inverters. Schneider Electric's sales representatives will help customers buy the correct type of inverter and associated wiring box. This solutions guide can be used to select the correct wiring box.

21. When does the temperature de-rating begin for Conext CL inverter? How much does it de-rate?



22. What if I install the Conext CL inverter in outdoor place?

    The Conext CL inverter is rated for outdoor duty. It can be installed as per instructions provided in the Installation Manual. For more information about outdoor installation, see the Installation manual.

23. What is the normal manufacturing time after confirmation of order for Conext CL inverters?

    Generally, it takes 10 to 14 weeks to manufacture CL125E inverters. We recommend clients consider this time along with shipping time to plan their project. If there is a steeper timeline, contact us for further discussion.

24. Where can I find the test certificates for Conext CL inverter?

    CL inverter certifications are available at

    http://solar.schneider-electric.com/product/conext-cl-125-string-inverter/

25. What type of warranty does Schneider Electric offer for Conext CL inverters?

    Warranty terms for Conext CL depends on the region of installation. Users can find the information about warranty at

    http://solar.schneider-electric.com/product/conext-cl-125-string-inverter/

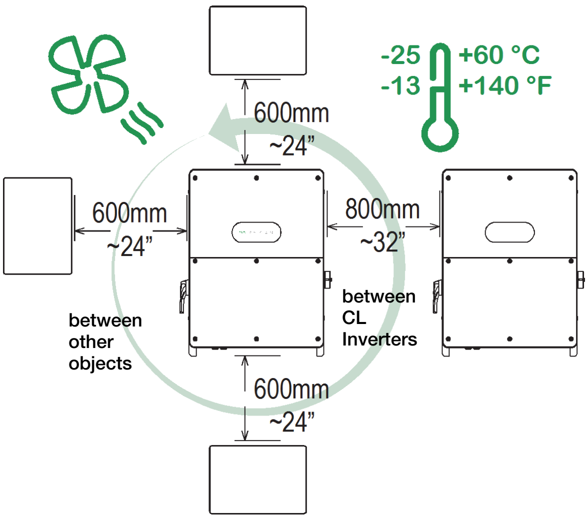
26. Do I need to oversize the transformer when I connect to multiple Conext CL inverters?

    We recommend equal or oversized transformer for Conext CL inverters. Especially when there is large number of CL inverters connected in parallel to one transformer low-voltage winding, we recommend oversizing the transformer by 10%. This is not mandatory.

27. What type of wiring schemes can Conext CL inverter be connected with?

    The Conext CL inverter can be connected with 600V, 3 Phase 3 wire WYE, or 3 wire DELTA wiring schemes.

28. How much space do I need to install Conext CL inverters side by side?



29. If any component inside the Conext CL inverter is damaged during installation how can I buy a new component?

    Contact your Schneider Electric sales representative to buy the components.

30. What type of monitoring system I can use with Conext CL inverters?

    The Conext CL inverter is compatible with all major third-party monitoring solutions. To plan your monitoring solution in advance, contact your Schneider Electric sales representative and the third-party monitoring solution provider.

31. Is it mandatory to use an AC circuit breaker at the output of Conext CL wiring box?

    We recommend that the installer / client uses the circuit breaker to support AC surge protection device.

32. What is the brief specification of DC and AC Surge protection devices provided in the wiring box of Conext CL inverters?

    Conext CL wiring boxes are equipped with Type 2 DC and AC surge protection devices.

    - DC SPD make: Citel, Type 2
    - AC SPD: Type 2 (AC SPD is not field replaceable)

33. What is the brief specification of DC Fuses provided in the Conext CL wiring box?

    Conext CLA inverters are equipped with touch safe Fuse holders. Inverters will be supplied with 15A gPV type fuses mounted in Fuse holders.

34. Is there an Anti-Islanding protection provided in the Conext CL inverter?

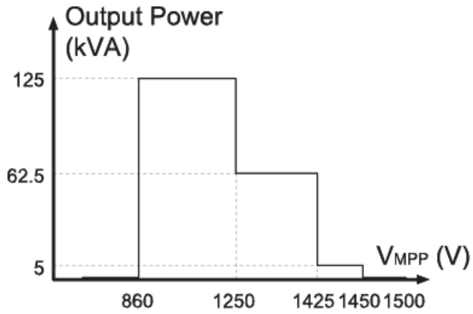
    Yes. The Conext CL inverter is equipped with anti-islanding protection.

35. What is the output operating voltage range capability/limits, response to network voltage sags?

    The inverter will deliver full power at unity power factor with +15% grid voltage variation.

36. What is the wake up value and power watt for Conext CL inverters?

    Wakeup voltage - 920 VDC at AC nominal voltage of 600VAC.



    The minimum start up power is 380 watts (Under normal Grid voltage, and PV voltage).

37. What is the latency to set the output of the inverter to 0% from100%?

    Two seconds (typical).

38. What is the latency to set the output of the inverter to 100% from 1%?

    ~500 ms.

39. Can we control the output of the inverter is 1% steps? What is the time resolution?

    1% steps is possible and time latency is ~500 ms.

40. How long does it take for a firmware upgrade over RS485 or eConfigure CL125 APP for a single inverter?

    10 to 15 minutes (approximately)

41. What is the value of the inverter's impedance?

    Calculation of the impedance at 175 Hz (R and X)

    R+jX = 0.006-22.7j

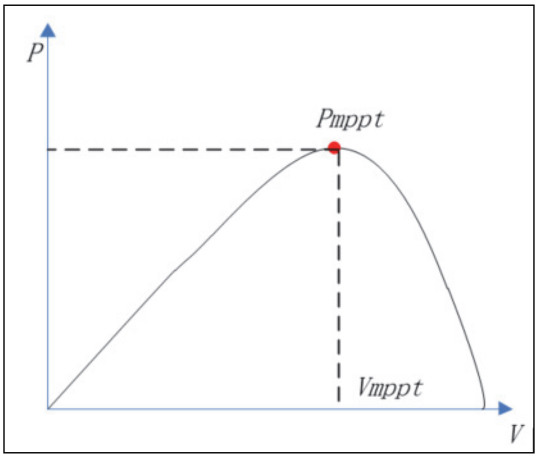
    Resistance = 0.006

    Reactance = -22.7j

42. Can we remotely reset (on or off) the inverter over Modbus?

    Yes.

43. Explain a detailed DC Voltage vs. power curve for operating, de-rated and off conditions with respect to specific voltage or range or voltage.



MPPT voltage range: 860 ~ 1450V

Full MPPT voltage range: 860 ~ 1250V

Maximum voltage: 1500V

Starting voltage: 920V

When the PV voltage is greater than 920V, the inverter began trying to connect to the grid, according to the MPPT tracking algorithm, the input voltage moves to the left step by step, eventually stabilizing in maximum power point.

When a derating event occurs, the input voltage from the maximum power point moves to the right, the input voltage is raised gradually decrease the power to achieve derating. When the inverter is insufficient light in the evening, if the input power is less than 80w, the inverter will off the grid, stop running.

44. What type and size of cable could be connected to the output of CL Inverters?

Type	**Terminals**	**Terminal type**	**Maximum cable aluminum**			**Maximum cable copper**		
			stranded	**Solid**		**stranded**	**Solid**	
				Round	**Sector**		**Round**	**Sector**
CL125E	L1 L2 L3 PE	Screw	4/5 wires with 185 mm^2	4/5 wires with 185 mm^2	4/5 wires with 185 mm^2	4/5 wires with 185 mm^2	4/5 wires with 185 mm^2	4/5 wires with 185 mm^2

45. What’s the switching frequency?

The switching frequency is 16 kHZ.

46. What's the self-consumption power of the CL Inverter?

CL Inverter power consumption information	Power Consumption
Self-consumption during operation (Excluding IGBT and fans)	70W
Self-consumption during operation (including IGBT and fans)	2450W
Consumption at night (Unit remain disconnected from grid)	<8W
Minimum power to start	380W
Self-consumption during operation (Excluding IGBT and fans)	70W

47. What is the CL Inverter's de-rating with respect to AC output voltage?

    When AC voltage increases, it won't result in derating, just power limitation because for the same power, current decreases. Only when AC voltage is decreasing, power decreases because after current reaches the rated maximum current, it can't be increased. At the same time, if the power decrease is due to a grid voltage decrease, the inverter won't display "derating".

    Vmin=480V: S=80 kVA

    Vnom=600V: S=125 kVA

    Vmax=690V: S=125 kVA

48. Does the inverter store any data? How much and what data is stored?

    The inverter stores preservation machine operation and fault information;
    1. operation information 5 minutes recording a record 30 days
    2. recent fault information recording 100.
    3. recently recorded event information 100
    4. monthly and annual energy production (power curve (7 days), generating capacity (about 365 days), monthly energy output (180 months), the generating capacity (30 years))

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As standards, specifications, and designs change from time to time, please ask for confirmation of the information given in this publication.

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