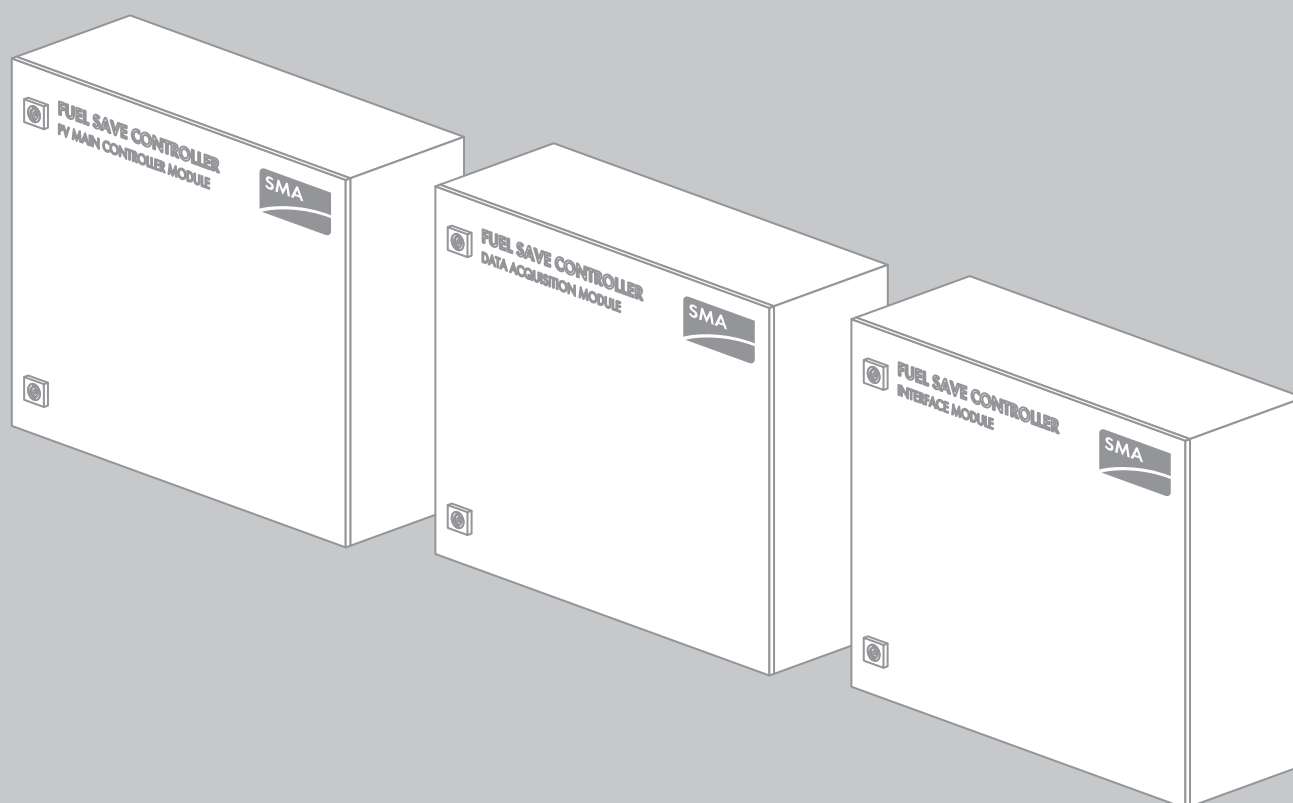


Technical Information: Functional Description

SMA FUEL SAVE CONTROLLER

PV Diesel Hybrid Systems



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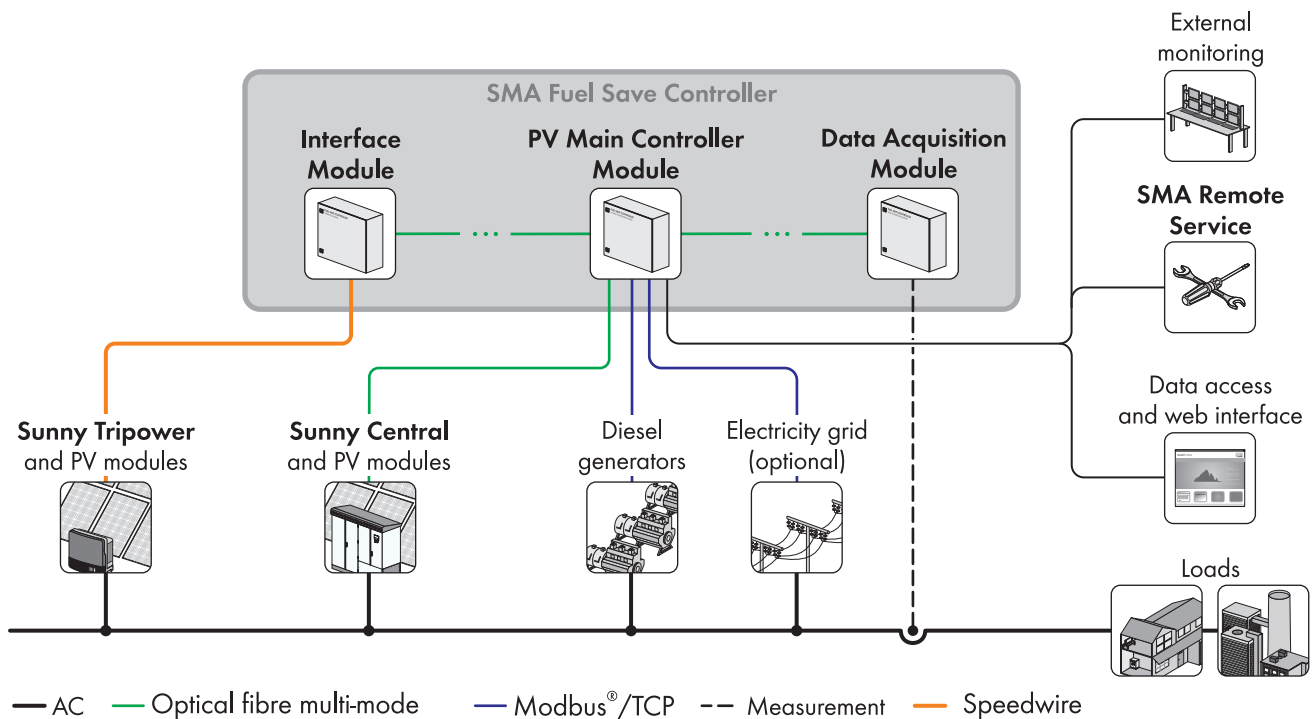
1 Introduction

Together with SMA PV inverters, the SMA Fuel Save Controller offers a system solution for the integration of large-scale PV power plants into electrical networks based on fossil-fuelled power generation units (gensets). The SMA Fuel Save Controller offers reliable control and monitoring of SMA PV inverters and allows a stable operation of the electrical network. For this purpose, the SMA Fuel Save Controller permanently monitors the status of the gensets and the loads and adjusts the power output of the SMA PV inverters accordingly. During the initial start-up, the system operator has the possibility to activate various functions for a stable and reliable system operation such as minimum genset loading and spinning reserve. In addition, it is possible to remotely monitor all relevant measurements, process data and the current system status via a SCADA system or a web-based user interface.

Primarily, the SMA Fuel Save Controller performs the following tasks:

- Monitoring of the gensets' power and operating status
- Monitoring of the load and grid status
- Calculation of suitable values for the maximum power output of the PV inverters according to defined parameter settings and the current status of gensets and load
- Control and communication interface to PV inverters
- Internal logging of all relevant system data
- Provision of relevant system data for local and remote monitoring
- Emergency shutdown of the PV inverters in case of a system malfunction

2 Block Circuit Diagram



Modbus® is a registered trademark of Schneider Electric licensed to the Modbus Organization, Inc.

Figure 1: Block circuit diagram

3 Description

3.1 Overview

The SMA Fuel Save Controller consists of three different module types. Each module type is designed to fulfil particular tasks. The PV Main Controller Module is the main control unit of the SMA Fuel Save Controller. The Data Acquisition Module is used to monitor the current load and the grid status. The Interface Module represents the interface to the PV inverters and is only required for Sunny Tripower inverters. The different modules are interconnected via an optical-fibre communication line that allows the modules to be installed in different locations. Optionally, copper-based communication is possible for distances below 100 m.

3.2 PV Main Controller Module

The PV Main Controller Module is the main control unit of the SMA Fuel Save Controller. It comprises monitoring of the gensets, logical control of the PV plant and an interface for local and remote monitoring.

The PV Main Controller Module uses Modbus/TCP to communicate with up to twelve peripheral devices. Depending on the configuration, it is possible to communicate with the following devices:

- With up to five genset controllers or five Data Acquisition Modules for genset measurement
- With up to four Data Acquisition Modules for load measurement
- With up to four Interface Modules or up to eight Sunny Centrals
- With a remote monitoring system (SCADA or web interface/FTP)

The standard setup allows for the communication with up to five genset controllers, one Data Acquisition Module and one Interface Module or one Sunny Central inverter. In case of additional requirements, further equipment might need to be installed.

The PV Main Controller Module monitors the gensets' operating state (online/offline) and their active and reactive power output via Modbus/TCP. For gensets without Modbus interface, it is alternatively possible to connect up to five Data Acquisition Modules to monitor up to five gensets. In combination with the system requirements defined during initial start-up and the information from load and grid measurements received from the Data Acquisition Module, the PV Main Controller Module calculates suitable maximum power values for the PV inverters (active and reactive power possible). These power values are communicated as setpoints via the Interface Module to the Sunny Tripower or directly to the Sunny Central inverters.

The PV Main Controller Module includes an interface for local and remote monitoring based on Modbus/TCP. For this purpose the PV Main Controller Module logs information about the inverter power and operating state, the load and the generator power and operating state in CSV format. The logged data is saved in five-second intervals for two days and as five-minute average value for 100 days and can be accessed by means of the integrated FTP server.

3.3 Data Acquisition Module

The Data Acquisition Module is an extension module to the PV Main Controller Module designed to acquire data from the electrical network or alternatively from gensets without Modbus interface. The Data Acquisition Module includes the measuring and data analysis electronics for a four-wire, three-phase grid connection. It measures voltage and current via external voltage and current transducers and calculates the current active and reactive power at the monitored metering point. The acquired data is transmitted to the PV Main Controller Module for further data processing. The external voltage and current transducers are not supplied by SMA Solar Technology AG.

3.4 Interface Module

The Interface Module is an extension module to the PV Main Controller Module. It represents the interface between the PV Main Controller Module and Sunny Tripower string inverters in decentralised PV plants. Due to the different communication concept in Sunny Central inverters, the Interface Module is not required if this inverter type is installed. The Interface Module includes the control unit for up to 75 Sunny Tripower inverters. It receives the setpoints for the defined inverter power output from the PV Main Controller Module and sets the power adjustments accordingly. For monitoring purposes, the Interface Module sends the inverter status and the relevant performance data to the PV Main Controller Module. The Interface Module, however, implements its own data-logging functions, including the registration of the SMA PV inverters in Sunny Portal.

4 Operation

4.1 Purpose of the SMA Fuel Save Controller

The SMA Fuel Save Controller has been designed to integrate SMA PV inverters into genset networks. The main purpose of the SMA Fuel Save Controller is to save fuel by substituting parts of the genset load with PV energy and to allow for a stable network operation at the same time. The PV plant can be regarded as a power generator operating in parallel with the gensets. As a supporting part of a genset network, it is mandatory to provide certain features related to power control, synchronisation and emergency operation. This can be assured with the installation of the SMA Fuel Save Controller combined with SMA PV inverters, even at a high PV penetration* of up to 60%. Nevertheless, the genset control system always remains the leading component of the network.

4.2 Operating Modes

The SMA Fuel Save Controller includes different operating modes that can be defined during system commissioning.

Operating Mode A

In operating mode A, the SMA Fuel Save Controller acts as the main control unit for the PV inverters. It permanently monitors the status and the power output of up to five gensets via a Modbus/TCP connection with the genset control units. Furthermore, it receives the acquired data for the load requirements and the grid status from the Data Acquisition Module and calculates a suitable setpoint for power output of the PV inverters under consideration of the conditions for the genset operation defined during initial start-up. These conditions are defined for each genset and include the following specifications:

- Apparent power (kVA)
- Active power (kW)
- Activation threshold (kW)
- Cut-out threshold (kW)
- Minimum load (kW)

Operating Mode B

The principle of operating mode B is mostly identical to operation mode A. It applies if there is no possibility to communicate with the gensets via Modbus/TCP. In this case, up to five Data Acquisition Modules can be installed to monitor up to five gensets via voltage and current measurement. The operating data processing and the PV plant control works the same way as in operating mode A.

Operating Mode C

Operating mode C applies if the genset network is supplied by more than five units or if the setpoints for the PV inverter power are separately calculated. In both cases, the SMA Fuel Save Controller does not monitor the gensets. Instead supervisory system controller needs to calculate the required setpoints for the PV inverter power output and communicate them to the SMA Fuel Save Controller via Modbus/TCP. The role of the SMA Fuel Save Controller in this case is to guarantee a fast communication with the PV inverters, to implement an emergency inverter shutdown function, a reverse power protection for the gensets and to provide access to SMA equipment for the SMA Service personnel.

* PV penetration is the ratio (in per cent) of the total maximum PV nominal plant power to the total maximum power of the gensets operated in parallel.

4.3 Operational Features

The control strategy of the SMA Fuel Save Controller allows for permanently stable system operation. Therefore, the SMA Fuel Save Controller offers several features that can be activated as required. Those features affect the behaviour of the SMA Fuel Save Controller and determine how it reacts in potentially critical scenarios or in operating states with optimising potential.

Minimum Genset Loading

Most gensets should not be operated below a certain power level to avoid inefficient operation, internal glazing and reverse power scenarios. In times of high solar irradiation a 'generously dimensioned' PV plant could unload the gensets below this threshold. In those scenarios the SMA Fuel Save Controller reduces the power output of the PV inverters typically within five to seven seconds. The power adaption rate is adjustable and can be modified if required.

Reverse Power Protection

If the SMA Fuel Save Controller detects a sudden load step (e.g. caused by load shedding or tripping of a protection device), the inverter power output is adjusted according to the defined power adaption rate. In critical situations this might be too slow to avoid a genset reverse power scenario (the PV inverters feed power into the gensets). In this case the SMA Fuel Save Controller forces the immediate shut-down of the PV inverters. The complete inverter shut-down takes less than 2.5 seconds.

Spinning Reserve

To ensure stable operation, the SMA Fuel Save Controller makes sure that there is always sufficient spinning reserve available from the gensets to solely manage the load, e.g. in case of scattered cloud drift or sudden load changes. In genset networks with more than one unit, the SMA Fuel Save Controller can make use of the existing genset management functions like the genset activation and cut-out thresholds. In scenarios where the activation of an additional genset is mandatory to offer sufficient spinning reserve, the SMA Fuel Save Controller temporarily reduces the power output of the PV inverters. As a result the genset loading is raised above the activation threshold of another genset and the starting process can be engaged by the genset controller. In the opposite case it is possible to deactivate one unit if the remaining genset(s) still meet(s) the spinning reserve requirements. Thus, the SMA Fuel Save Controller temporarily allows for additional PV power to lower the genset loading in order to reach its cut-out threshold.

Inverter Power Adaption Rate

The power adaption rate of the PV inverter can have significant influence on the stability of a genset-based grid. Therefore, the SMA Fuel Save Controller allows the determination of the adaption rate (ramp rate) of the PV inverter power output. This function only applies to controlled power adjustments and does not affect the 'natural' behaviour of the inverter caused by changing solar irradiation conditions.

Reactive Power Management (Optional)

Within a certain range SMA PV inverters are capable to support gensets with reactive power. By activating the reactive power management the SMA Fuel Save Controller creates a setpoint for the reactive power output of the PV inverters based on the current ratio of the active and reactive power demand. This leads to a lower reactive power loading of the gensets.

Micro-Grid Friendly (Optional)

The feature "Micro-Grid Friendly" manages the behaviour of the SMA Fuel Save Controller in systems that mainly rely on an electricity grid which uses gensets as a backup power supply. During power cuts the gensets supply the loads and can act as a reference for the PV inverters to synchronise to.

When the electricity grid returns after a power cut, the SMA Fuel Save Controller temporarily reduces the power output of the PV inverters to an adjustable level to allow a smooth synchronisation of electricity grid and gensets. After the resynchronisation and connection process the inverter power output is increased again. The synchronisation process of gensets and grid is not controlled by the SMA Fuel Save Controller.

In this system configuration the grid monitoring of the PV inverters has to be adjusted according to the requirements of a genset-parallel operation. In some cases the required settings might not be accepted for grid-parallel operation. Therefore, permission of the local network operator is required.

Feed-In Protection (Optional)

The feature "Feed-In Protection" determines the behaviour of the SMA Fuel Save Controller in systems supplied by an electricity grid or an electricity grid combined with backup gensets. The purpose of this feature is to prevent the PV inverters from feeding into the electricity grid where this is not permitted. This feature is comparable with the generator minimum load feature and limits the power output of the PV inverters according to the defined minimum load of the electricity grid.

5 Influence of PV Inverters

PV inverters integrated in a genset-based network influence the grid parameters, especially voltage and frequency. This impact is very low in case of an PV penetration of 10% to 15% of the total rated apparent power of the gensets operated in parallel. The genset controller balances the influence caused by the inverters and maintains the grid stability. The impact level increases with higher PV penetration. If the PV penetration exceeds 20%, special control mechanisms, e.g. load-dependent frequency variation, have to limit the impact of the PV plant on the grid to avoid critical scenarios. Integrating the SMA Fuel Save Controller into a PV hybrid system ensures a stable system operation up to a PV penetration of 60%.

The SMA PV inverters act as a current source. This means that they always have to follow a reference grid. The inverters self-synchronise, permanently monitor the grid status and feed-in power as long as the grid voltage and frequency remain within a predefined range. In extreme situations the stability of the network has the highest priority. If voltage or frequency should exceed the accepted limits, the inverters switch off immediately and remain switched off as long as they register a violation of the accepted limits. This behaviour allows a straight forward and safe integration of SMA PV inverters into the genset network.

In PV hybrid systems, SMA inverters react on the setpoints defined and transmitted by the SMA Fuel Save Controller with a varying power output. This is realised by a dynamic variation of the inverter operating point. The power output is continuously variable.

Standard PV inverters usually feed in pure active power into the grid. In some situations this can lead to disadvantageous genset operating states. Loads with high reactive power demand force the gensets to operate with an unfavourably low power factor. To reduce this effect and to support the generators to stabilise the system voltage, the PV inverters can be remotely controlled to compensate a certain amount of reactive power. Sunny Tripower string inverters can be operated with a minimum power factor of 0.8, Sunny Central CP inverters with 0.9, both overexcited and underexcited. The power factor of the inverter is electronically controlled, can be changed without any delay and has no negative impact on the inverter.

6 Technical Data

6.1 PV Main Controller Module

Mechanical Data

Width x height x depth	600 mm x 600 mm x 210 mm
Weight	30 kg
Degree of protection according to IEC 60529	IP65

Climatic Requirements

Operating temperature	– 10°C to +50°C
Humidity, non-condensing	5% to 95%
Maximum installation height above MSL	2,000 m

Voltage Supply

Voltage	110 V to 240 V
Frequency	50 Hz to 60 Hz
Maximum power	200 VA
Maximum back-up fuse	Miniature circuit-breaker 10 A, type B
Type of connection	Spring clamp terminal
Conductor cross-section	1.5 mm ² to 2.5 mm ²

Communication

Communication SMA Fuel Save Controller with power plant control, SCADA and remote monitoring	Modbus/TCP, HTTP, FTP via Ethernet 10 BASE-T, Ethernet 100 BASE-T(X)
Communication between the modules	Ethernet 100 BASE-FX or Ethernet 100 BASE-TX
Communication with Sunny Tripower*	Speedwire, 10/100 Mbit/s
Communication with Sunny Central	Ethernet, 100 BASE-FX or 100 BASE-TX**
Communication with genset control	Modbus/TCP via Ethernet 10 BASE-T or Ethernet 100 BASE-T(X)
Type of connection for Ethernet BASE-T(X)	RJ45
Type of connection for Ethernet BASE-FX	SC

* Interface modules required

** Optional

Multifunctional Switching Inputs

Number	8
Terminal voltage at 0 mA	24 V
Maximum voltage drop at 10 mA	5 V
Connectable switches	Potential-free switches
Type of connection	Spring clamp terminal
Conductor cross-section	1.5 mm ² to 2.5 mm ²

Multifunctional Switching Outputs

Number	4
Terminal voltage	Potential-free
Maximum of connectable switching voltage	250 V
Maximum signal current	6 A
Type of connection	Spring clamp terminal
Conductor cross-section	1.5 mm ² to 2.5 mm ²

Visualisation/Web Interface

Visualisation and configuration interface	Ethernet interface for a Touch Web Panel or external computer with Internet browser
Access to visualisation and configuration interface	Local or remote
Recording of measured values	Instantaneous values every five seconds and mean values every five minutes
Real-time visualisation of predefined values	Yes
Recording of events	Logbook
Access to data	Via the integrated FTP server

Compatibility

Compatibility with PV inverters	Sunny Central SCxxxCP Sunny Central SCxxxCP XT Sunny Tripower 10000TL** Sunny Tripower 12000TL** Sunny Tripower 15000TL** Sunny Tripower 15000TL Economic Excellence** Sunny Tripower 17000TL** Sunny Tripower 20000TL Economic Excellence**
Maximum degree of penetration*	60%
Maximum number of handled gensets	5

* Degree of penetration is the ratio (in per cent) of the total installed PV inverter power to the total maximum power of the gensets operated in parallel.

** Interface module and SMA Speedwire/Webconnect data module are required.

6.2 Data Acquisition Module

Mechanical Data

Width x height x depth	600 mm x 600 mm x 210 mm
Weight	30 kg
Degree of protection according to IEC 60529	IP65

Climatic Requirements

Operating temperature	– 10°C to +50°C
Humidity, non-condensing	5% to 95%
Maximum installation height above MSL	2,000 m

Voltage Supply

Voltage	110 V to 240 V
Frequency	50 Hz to 60 Hz
Maximum power	200 VA
Maximum back-up fuse	Miniature circuit-breaker 10 A, type B
Type of connection	Spring clamp terminal
Conductor cross-section	1.5 mm ² to 2.5 mm ²

Communication

Communication between the modules	Ethernet 100 BASE-FX or Ethernet 100 BASE-TX
Type of connection for Ethernet BASE-T(X)	RJ45
Type of connection for Ethernet BASE-FX	SC

Multifunctional Switching Inputs

Number	2
Terminal voltage at 0 mA	24 V
Maximum voltage drop at 10 mA	5 V
Connectable switches	Potential-free switches
Type of connection	Spring clamp terminal
Conductor cross-section	1.5 mm ² to 2.5 mm ²

Switching Output of the Overvoltage Protection

Number	1
Terminal voltage	Potential-free
Maximum of connectable signal voltage	250 V
Maximum AC signal current	0.5 A
Maximum DC signal current	0.1 A
Type of connection	Spring clamp terminal
Conductor cross-section	1.5 mm ² to 2.5 mm ²

Measurement Inputs

Number of voltage measuring inputs	4
Measurement range of the voltage measurement between phase conductor and neutral conductor	0 V to 300 Vrms
Measurement range of the voltage measurement between phase conductor and phase conductor	0 V to 415 Vrms
Resolution of voltage measurement	10 mV
Impedance	4 MΩ per phase conductor
Number of current measuring inputs	4
Current measurement range	0 A to 5 A
Resolution of current measurement	1 mA
Type of connection	Spring clamp terminal
Conductor cross-section	1.5 mm ² to 2.5 mm ²

6.3 Interface Module

Mechanical Data

Width x height x depth	600 mm x 600 mm x 210 mm
Weight	30 kg
Degree of protection according to IEC 60529	IP65

Climatic Requirements

Operating temperature	– 10°C to +50°C
Humidity, non-condensing	5% to 95%
Maximum installation height above MSL	2,000 m

Voltage Supply

Voltage	110 V to 240 V
Frequency	50 Hz to 60 Hz
Maximum power	200 VA
Maximum back-up fuse	Miniature circuit-breaker 10 A, type B
Type of connection	Spring clamp terminal
Conductor cross-section	1.5 mm ² to 2.5 mm ²

Communication

Communication SMA Fuel Save Controller with power plant control, SCADA and remote monitoring	Modbus/TCP, HTTP, FTP via Ethernet 10 BASE-T, Ethernet 100 BASE-T(X)
Communication between the modules	Ethernet 100 BASE-FX or Ethernet 100 BASE-TX
Communication with Sunny Tripower	Speedwire, 10/100 Mbit/s
Type of connection for Ethernet BASE-T(X)	RJ45
Type of connection for Ethernet BASE-FX	SC

Visualisation/Web Interface

Visualisation and configuration interface	Ethernet interface for a Touch Web Panel or external computer with Internet browser
Access to visualisation and configuration interface	Local or remote

Compatibility

Compatibility with PV inverters	Sunny Tripower 10000TL* Sunny Tripower 12000TL* Sunny Tripower 15000TL* Sunny Tripower 15000TL Economic Excellence* Sunny Tripower 17000TL* Sunny Tripower 20000TL Economic Excellence*
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* SMA Speedwire/Webconnect data module is required.

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