

Ingeteam's SPE, the Single Pair Ethernet communication network

Technical Guide

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1 About this guide

The purpose of this guide is to describe the architecture, configuration, design and commissioning of Ingeteam's *SPE (Single Pair Ethernet)* communication network.



To download the last version of this guide visit www.ingeteam.com.

1.1 Scope and nomenclature

In this document, the generation units will be generically referred as *inverter* and the photovoltaic system will be referred to as *the installation* or *the plant*.

1.2 Recipients

The connection of the system is intended for qualified personnel only. This refers to workers who can certify the qualifications to meet every safety standards, regulations and laws applicable to the tasks of installing and operating all the components of the system.

The responsibility for designating these qualified workers will always belong to the company they work for. It is necessary to decide which workers are suitable or not for carrying out a specific work to preserve their safety while complying with occupational safety legislation.

These companies are responsible for providing appropriate training in electrical equipment to their personnel and for explaining them the contents of this guide.

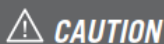
The final configuration of the system is intended for the end user.

1.3 Symbols

Throughout this guide we include warnings to highlight certain information. Relative to the nature of the text, there are three types of warnings:



This indicates a hazard to personnel or the device.



Indicates importance.



Additional information or references to other parts of the document or documents.

2 Description of the communication network

2.1 General vision

Single Pair Ethernet (SPE) has emerged as a transformative technology for communication and data transmission. SPE is a communication technology that allows data transmission over a single twisted pair of wires. Traditionally, Ethernet networks have used multiple pairs of wires for communication, such as the widely known 4-pair Category 5 or Category 6 cables. However, with the increasing demand for connectivity in various industries, there has been a need to transmit Ethernet signals over a single pair of wires to reduce cabling complexity and enable data transmission in space-constrained environments.

SPE is based on the Ethernet standard, which defines the rules for data transfer and network communication.

Ingeteam implements SPE 10BASE-T1L standard, which provides a data rate of 10 Mbps (megabits per second) over a distance of up to 1000 meters.

2.2 SPE vs traditional communication buses (RS485 and PLC)

SPE 10BASE-T1L offers significant advantages over traditional communication buses such as RS485 and PLC.

High-Speed Data Transmission

SPE 10BASE-T1L provides high-speed data transmission over a single pair of wires, offering a remarkable improvement over the limited bandwidth of RS485 and PLC buses. With data rates of up to 10 Mbps, SPE 10BASE-T1L enables faster and more efficient communication, making it suitable for applications requiring real-time data exchange or high-bandwidth requirements.

Longer Reach and Greater Flexibility

Compared to RS485 and PLC, SPE 10BASE-T1L offers extended reach and greater flexibility. It allows data to be reliably transmitted over longer distances, up to 1000 meters, without sacrificing signal integrity. This makes SPE 10BASE-T1L ideal for photovoltaics plants where communication signals need to travel considerable distances.

Simplified Infrastructure

SPE 10BASE-T1L significantly simplifies infrastructure requirements when compared to RS485 and PLC. It achieves high-speed communication using only a single pair of wires, reducing cabling complexity and saving installation costs. The simplified infrastructure also provides greater flexibility during network deployments, making it easier to adapt to evolving connectivity needs.

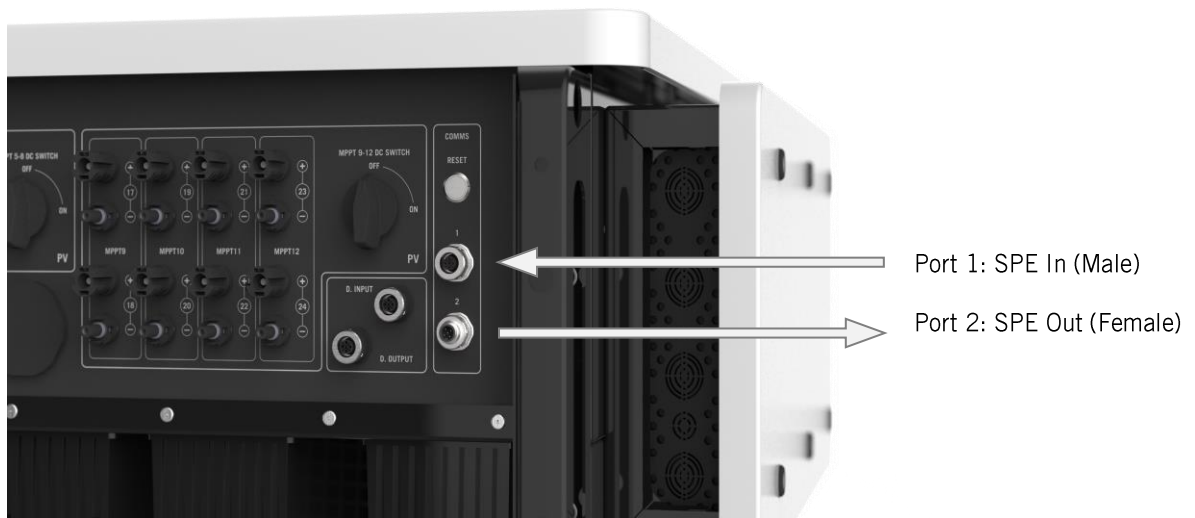
Enhanced Electromagnetic Compatibility (EMC)

SPE 10BASE-T1L is designed to provide robust performance in challenging electromagnetic environments. It utilizes advanced signal encoding techniques and features improved electromagnetic compatibility (EMC), allowing it to operate reliably even in the presence of electrical noise and interference. This makes SPE 10BASE-T1L more resistant to signal degradation compared to RS485, ensuring consistent and high-quality data transmission.

2.3 SPE devices

A photovoltaic SPE network plant consists of two main devices:

- **Inverters:** Each inverter has a three port embedded SPE switch. External port 1 (SPE In, male) is used to connect to the SPE network and external port 2 (SPE Out, female) is used to provide connectivity to other inverters on a daisy-chain topology. The third internal port is used to provide connectivity to the inverter's network processor.



- **SPE to Ethernet Switches:** An Ethernet to SPE switch is a networking device that serves as an interface between traditional Ethernet networks and Single Pair Ethernet (SPE) networks. It allows the integration of devices and systems that use Ethernet protocols with those that utilize SPE technology.

Several companies provide SPE 10BASE-T1L to Ethernet switches. Typical switches include 8 or 16 SPE ports and a several standard Ethernet ports.

From a conceptual point of view, the SPE network is like having all nodes connected to the same *Ethernet network*, which makes it transparent to higher level protocols such as TCP/IP.

INFO

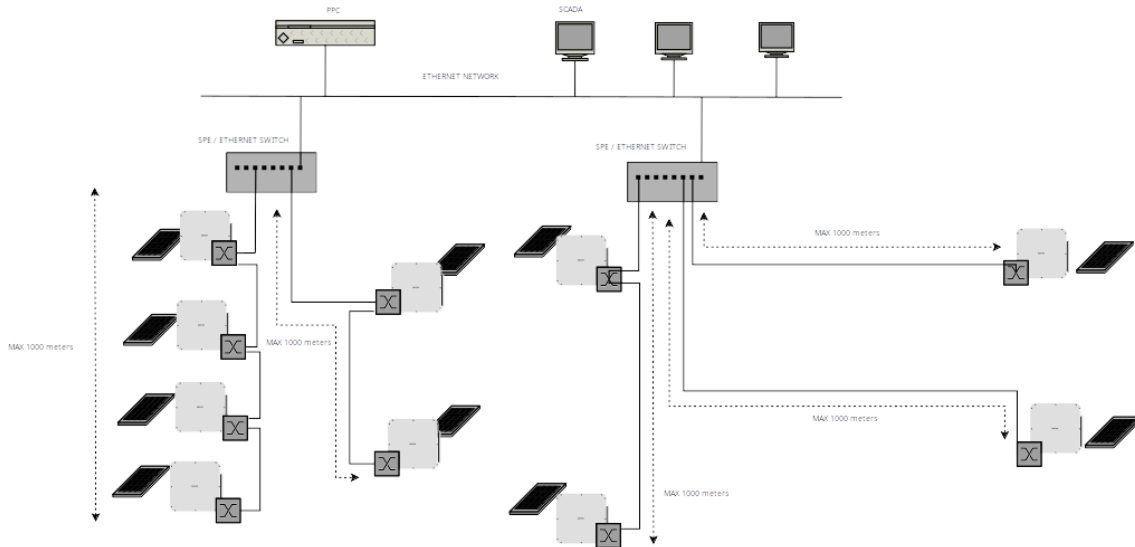
All the devices of the *SPE* network should have a static IP address associated within the same network.

2.4 SPE Network topology

The SPE network topology consists of one or more SPE to Ethernet switches, the inverters, the SCADA and the power plant controller.

The Ethernet segment of the network contains typical photovoltaic plant devices like a SCADA or a PPC.

On each SPE port of those switches, several inverters can be connected on a daisy-chain topology. The maximum wire distance from the SPE switch port to it's furthest inverter is limited by the SPE standard to 1000 meters.



Example of Ingeteam's SPE network for a typical plant.

A daisy chain network topology is a network configuration where devices are connected in a linear fashion, forming a chain-like structure. In this topology, each device in the network is connected to two neighbour devices, except for the first and last devices in the chain.

The up path refers to the direction in which data travels from the first device in the chain towards the last device. It can also be considered as the direction of data flow from the source or origin of the daisy chain to the endpoint.

The downward path, on the other hand, refers to the opposite direction of data flow, starting from the last device in the chain and moving towards the first device. It represents the path data takes when it needs to be transmitted back towards the source or origin of the daisy chain.

To summarize:

- Up path: Data flows from the first device towards the last device, or from the source to the endpoint.
- Downward path: Data flows from the last device towards the first device, or from the endpoint back to the source.

INFO

Each inverter connected on daisy chain introduces a latency of 2 milliseconds to the rest of the inverters on the downward path. To maintain network throughput and latency on acceptable values a maximum of 6 inverters connected on daisy chain is recommended.

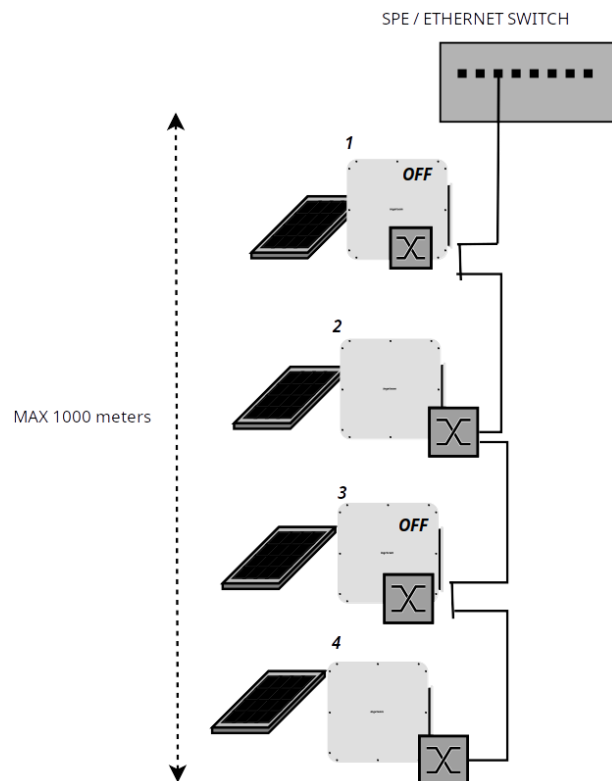
2.5 Fault tolerant network

In order to achieve a fault tolerant network the embedded SPE switch present at the inverter short circuits when the inverter is off and it only starts working when the inverter is properly initialized and running.

When an inverter is switched off because it is broken or has no power, it behaves as a closed cable segment from the SPE network point of view. The inverters on the downward path of the broken inverter can communicate with the rest of the network.

Example

On the following image inverters 1 and 3 are off so it's SPE switch ports 1 and 2 are short circuited. Inverters 2 and 4 can communicate with the rest of the network because the maximum cable length between them and the SPE Ethernet switch is less than 1000 meters.



Once inverter 1 powers on the embedded SPE switch present on the inverter opens the short-circuit relay and inverter 1 can communicate through the SPE network.

2.6 Physical inverter removed

In case that one inverter has to be physically removed (because it must be repaired, for instance), just connect the two SPE wires to maintain the continuity of the bus, and the rest of the inverters will communicate through the SPE network.

2.7 Supported switches

Ingeteam has performed interoperability tests with the following SPE switches.

- Phoenix Contact
<https://www.phoenixcontact.com/es-es/productos/industrial-ethernet-switch-fl-switch-2303-8sp1-1278397>
- Weidmüller
https://www.weidmueller.com/int/solutions/single_pair_ethernet/index.jsp

INFO

SPE 10BASE-T1L is an IEEE standard, so all switches and devices complying with the standard should properly interoperate with Ingeteam inverters even if they are not on the tested list.

2.8 Cable Types

SPE 10BASE-T1L standard use a single pair cable and has a maximum range of 1000 meters. However depending on the cable diameter the maximum distance of 1000 meters could not be reached. Here is a list with typical cable diameters and it's corresponding maximum distance.

- AWG 18, up to 1000 meters distance
This is the cable recommended by the SPE 10BASE-T1L standard.
- AWG 20, up to 800 meters distance
- AWG 23 single pair up to 500 meters distance

INFO

Due to availability reasons, a Profinet 2 pair cable can be used on an SPE network leaving one of the pairs unused.

INFO

Typical photovoltaic plant cable installation should employ a shielded twisted pair cable designed for exterior use.

2.9 Transmission speed and latency

Maximum transmission speed is 10Mbps per each SPE switch port. All inverters connected on daisy chain to the same SPE switch port share these 10Mbps. As the SPE signal is received and transmitted on the internal SPE switch embedded on the inverter latency is incremented with each inverter connected on daisy chain by 2 milliseconds per connected inverter.

CAUTION

Ingeteam states that the SPE network should not have more than 6 inverters connected on daisy chain, that is, connected to the same SPE switch port.

3 Plant example

3.1 14MW Photovoltaic plant

This is an example of a 14MW photovoltaic plant, based on 80 INGECON SUN 3Play 350kW inverters distributed in the plant. For the network connection, there are two SPE switches with 8 SPE ports each. With this distribution, 5 INGECON SUN 3Play 350kW inverters are connected on a daisy-chain topology on each SPE switch port.

With this topology the network characteristics are:

- The network bandwidth available per each inverter is $10 \text{ Mbps} / 5 = 2 \text{ Mbps}$
- The worst-case latency introduced by the SPE network would be $5 \times 2 \text{ ms} = 10 \text{ ms}$

