



EXPERT WORKSHOP SERIES

Part 2: Line Differential Protection - Interfaces

Agenda

1 Protection Interfaces and Communication converters

2 Advanced vs. Classic Protection Interface

3 Advanced Protection Interface DIGSI 5 Demo

- Redundant communication
- Multiplexed operation
- 4 end ring topology

4 Line Differential Protection over IP

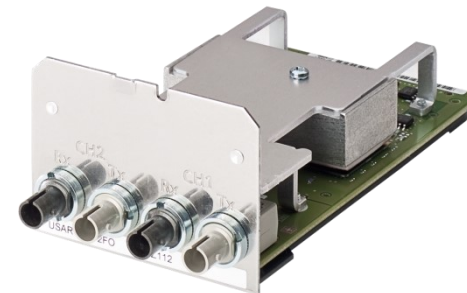
5 Line Diff. over IP DIGSI 5 Demo

Protection Interfaces

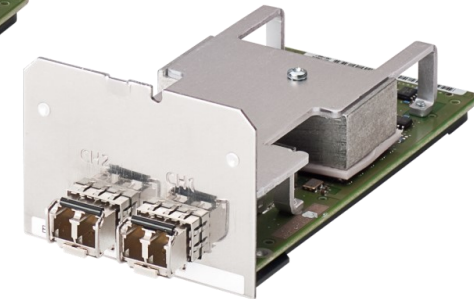
Protection Interfaces

SIPROTEC 5 Communication Options

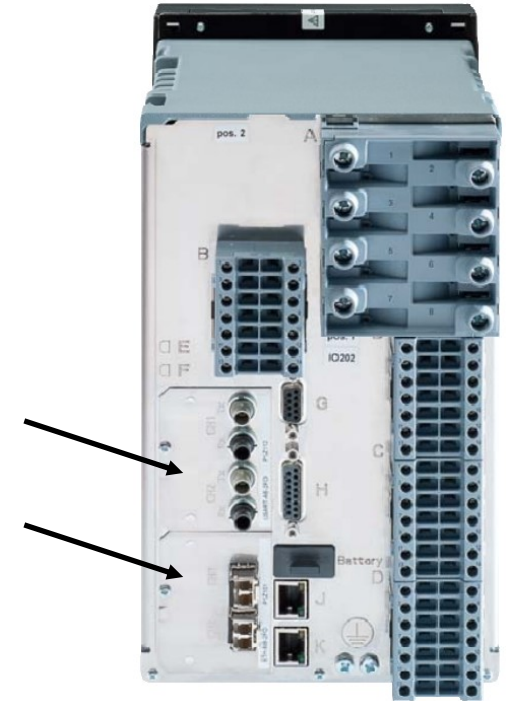
- Direct fiber optic (FO) connections
 - 2 km (multi-mode) ... 100 km (single-mode)
- Extended distance using FO repeater
 - up to 170 km (cascaded up to 3x 170 km)
- Pilot wire communication converter (SHDSL)
 - up to 20 km (2-wire Cu, twisted pair)
- Multiplexer connections for WAN
 - Interfaces: IEEE C37.94 (opt.), E1 (el.), X.21, ...
 - Legacy: SDH technology (end of lifetime)
 - Today: MPLS over DWDM networks
- Direct IP-based / Ethernet connection



USART-AE-2FO module
(2x ST, 820 nm)



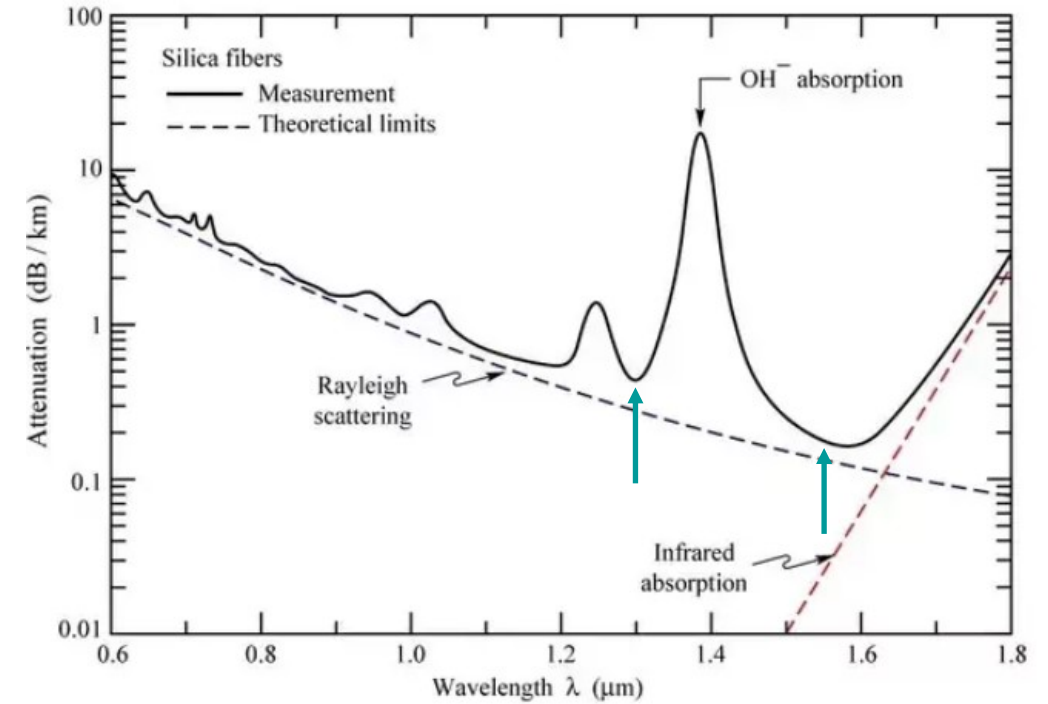
USART-Ax-2LDFO module
ETH-BD-2FO module
(2x LC, SFP)



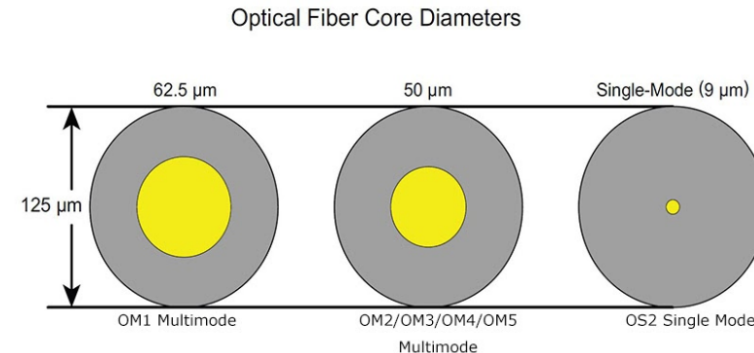
Protection Interfaces

Fiber Optics (FO) – Basics

- Multi-mode FO (820 nm, 62.5 μm or 50 μm core)
 - Access to multiplexers
 - Short direct FO applications
- Single-mode FO (1310 nm, 1550 nm, 9 μm core)
 - Long distance FO applications
- Confusion: 1300 nm or 1310 nm ?
 - Multi-mode FO → LED as source → 1300 nm
 - Single-mode FO → Laser as source → 1310 nm
- Single-mode LC connector polish
 - Straight physical contact (“PC” type) → SIP 5
 - Angled physical contact (“APC” type) → DWDM



Measured damping of fiber optics
(source: E.F. Schubert, Cambridge Uni. Press)

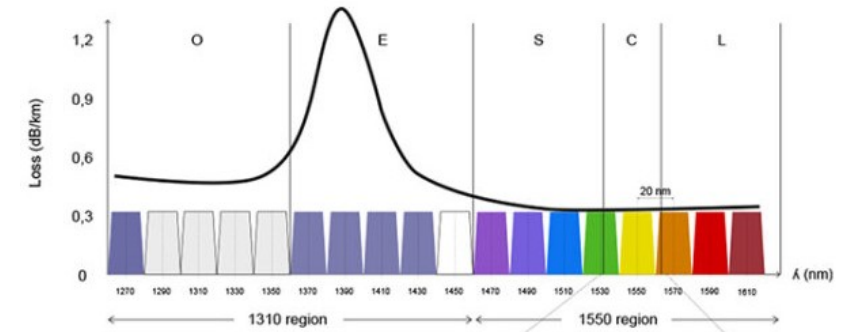
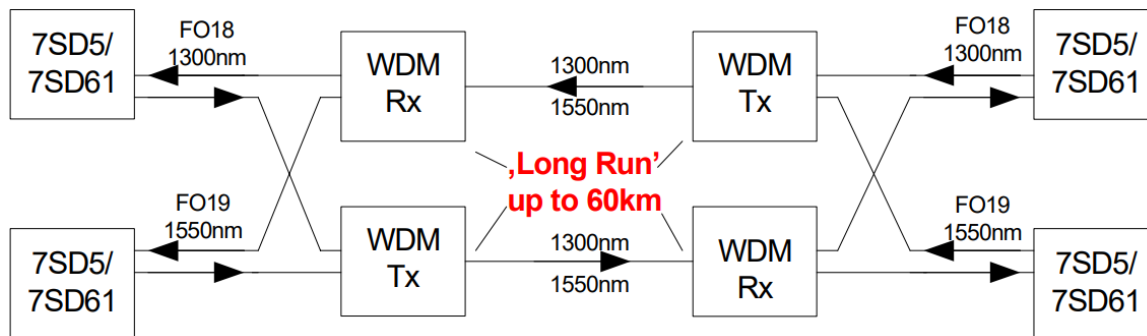


(source: <https://community.fs.com/>)

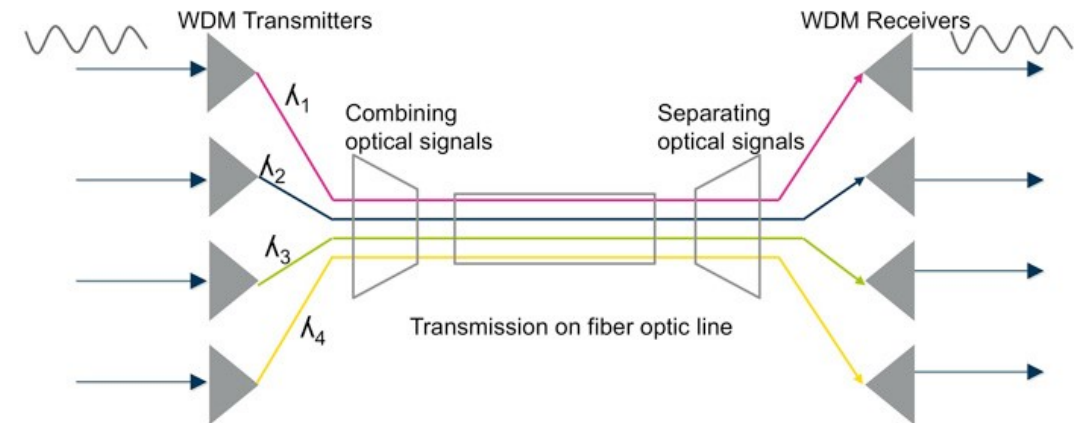
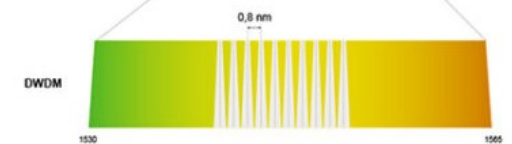
Protection Interfaces

Fiber Optics (FO) – Wavelength Division Multiplexing (WDM)

- WDM normal WDM (2 channels)
1310 nm and 1550 nm
- CWDM Coarse WDM (typ. 16 channels)
1270 nm – 1610 nm; 20 nm
- DWDM Dense WDM (typ. 40 channels)
1530 nm – 1565 nm; 0.8 nm
- Special FO application using both wavelength on a single fiber (example SIPROTEC 4)



(source: smartoptics.com)

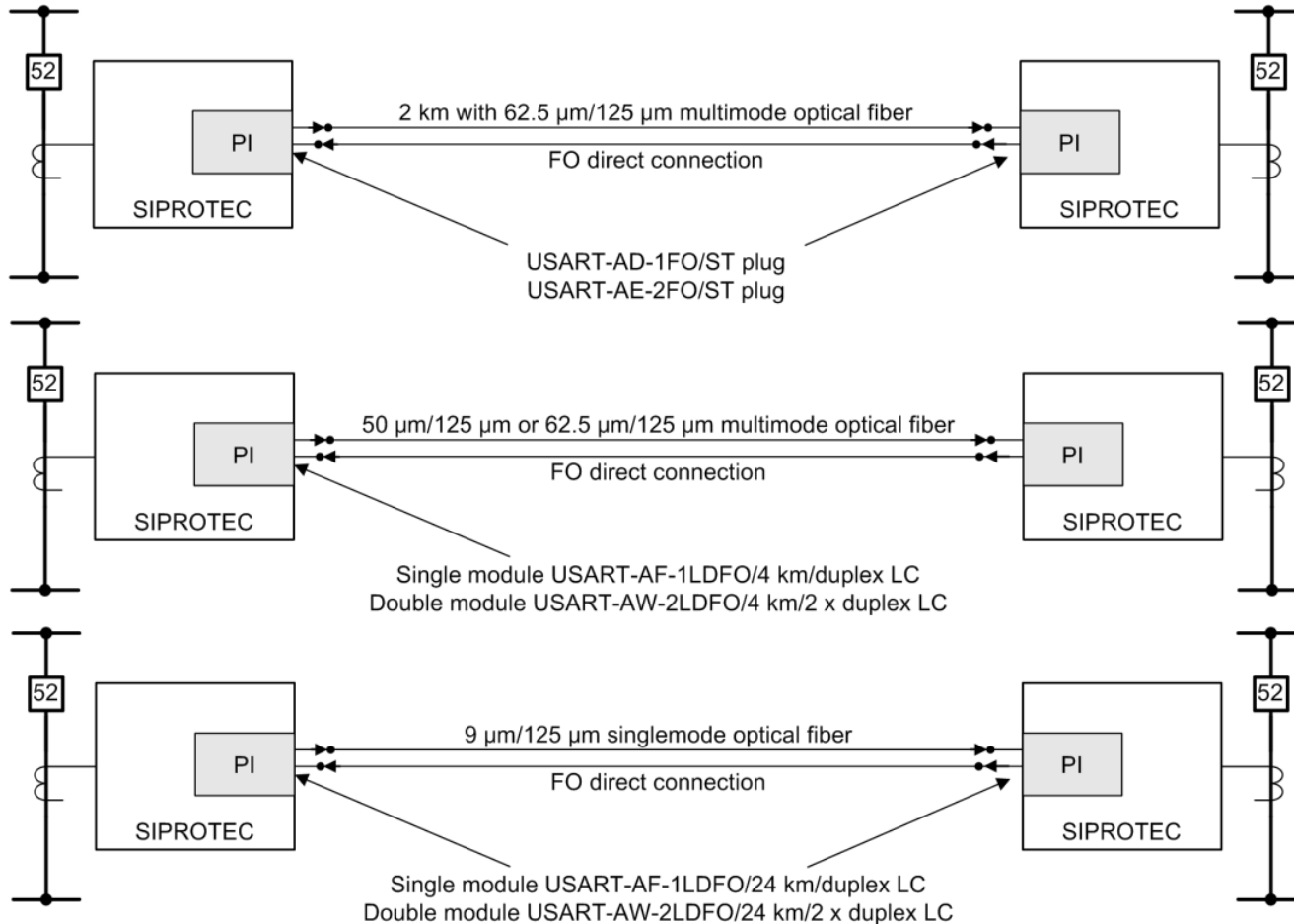


(source: www.community.fs.com)

Protection Interfaces

Direct Fiber Optic Connection

- Protection interfaces for different distances, MM/SM



Settings

Channel 1 settings

> Protection-Interface Settings

> > Device combin.

Device combin. settings

31.5131.102	Address of device 1:	101
31.5131.103	Address of device 2:	102
31.5131.101	Local device is device:	1
31.5131.122	Lowest appearing bit rate:	2048 kBit/s
31.5131.126	Connection mode:	SIPROTEC 5

> > Prot.interface

Prot.interface settings

102.1031.6231.105	Connection via:	fiber optic
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Protection Interfaces

Communication channel supervision

Channel Supervision of

- Correct device topology during handshake
- Number of telegrams send (Tx) and received (Rx)
- Thresholds for Error Rates per minute / per hour
 - Error indications for logs
- Synchronization supervision (DTO measures)
- Jumps and Asymmetry detection

Redundant communication channels

- Selection of channel with higher bandwidth (setting)

Ring topology

- Hot-standby connection between devices #1 and #2
- Automatic changeover from ring to chain in case of failure

Device combin. settings

31.5131.102	Address of device 1:	101	
31.5131.103	Address of device 2:	102	
31.5131.101	Local device is device:	1	
31.5131.122	Lowest appearing bit rate:	64 kBit/s	
31.5131.126	Connection mode:	SIPROTEC 5	

Prot. interf.1 settings

31.5161.1	Mode:	on	
31.5161.105	Max. error rate per hour:	1	%
31.5161.106	Max. error rate per min:	1	%
31.5161.107	Disturbance alarm after:	0.1	s
31.5161.108	Transm. fail. alarm after:	6	s
31.5161.109	Delay time threshold:	30	ms
31.5161.110	Difference Tx and Rx time:	0.1	ms
31.5161.113	Synchronization:	External synchron. off	

Protection Interfaces

Direct fiber optic connection – Optical budget

Calculation example:

- Transmitter min. output power $P_{T,min} = -5 \text{ dBm}$
- Receiver max. sensitivity $P_{R,max} = -34 \text{ dBm}$
- Optical power budget $OPB = P_{T,min} - P_{R,max} = -5 \text{ dBm} + 34 \text{ dBm} = 29 \text{ dB}$ (Note: difference in dB)

1310 nm single-mode FO with 20 splices and 10 connections:

- Single-mode FO losses $\alpha = 0.33 \frac{\text{dB}}{\text{km}}$
- Splice losses $20 \cdot 0.05 \text{ dB} = 1 \text{ dB}$
- Connection losses $10 \cdot 0.15 \text{ dB} = 1.5 \text{ dB}$
- Safety margin 3 dB (recommended)

$$\rightarrow \text{max. distance: } l_{max} = \frac{OPB - \sum \text{losses}}{FO \text{ losses/km}} = \frac{29 \text{ dB} - 2.5 \text{ dB} - 3 \text{ dB}}{0.33 \frac{\text{dB}}{\text{km}}} = 71 \text{ km}$$

Fiber optic	Damping coefficient
Multi-mode 850 nm	2.5 dB/km
Multi-mode 1300 nm	0.7 dB/km
Single-mode 1310 nm	0.33 dB/km
Single-mode 1550 nm	0.2 dB/km

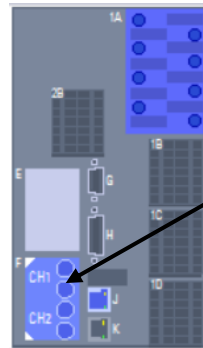
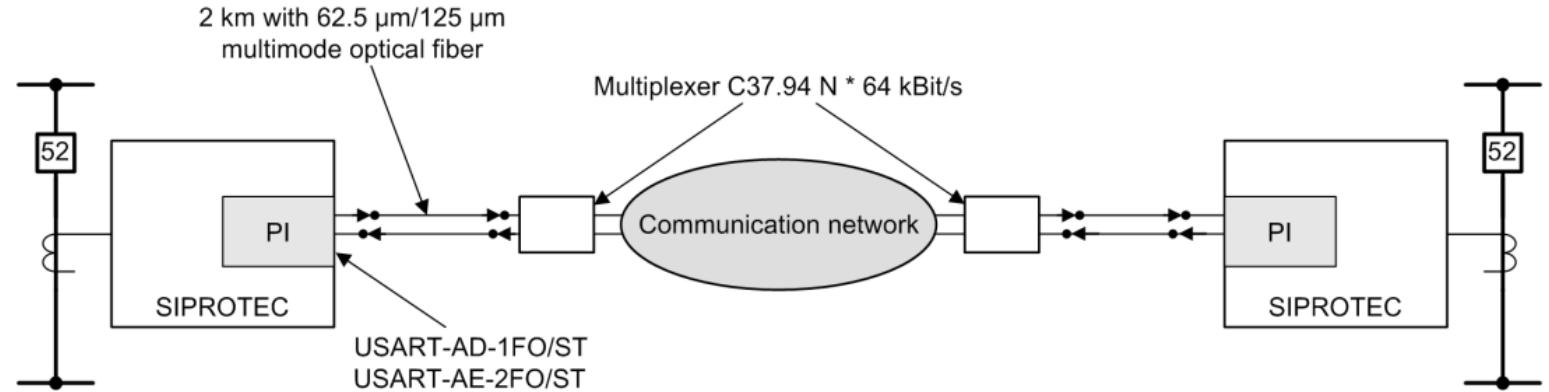
FO connections	typ. losses
Single-mode splice	0.05 dB
Multi-mode connection	0.2 ... 0.5 dB
Single-mode connection	0.1 ... 0.2 dB

Protection Interfaces

IEEE C37.94 Optical

Standardized protection interface

- Direct connection to multiplexer
- $N * 64 \text{ kBit/s}$ Interface
- Time slots $N = 1, 2 \text{ or } 8$



> > Prot.interface

Prot.interface settings

102.1031.0.105 Connection via: C37.94 1 * 64 kBit/s

> > Prot. interf.1

Prot. interf.1 settings

31.5161.1	Mode: on
31.5161.105	Max. error rate per hour: 1 %
31.5161.106	Max. error rate per min: 1 %
31.5161.107	Disturbance alarm after: 0.1 s
31.5161.108	Transm. fail. alarm after: 6 s
31.5161.109	Delay time threshold: 30 ms
31.5161.110	Difference Tx and Rx time: 0.25 ms
31.5161.113	PPS synchronization: PPS sync. off

→ Consider channel asymmetry of 0,3 ms ... 0,6 ms for this type of communication

Protection Interfaces

IEEE C37.94 Optical

End-to-end network communication delay depends on:

- Used Bitrate ($N * 64$ kBit/s) of protection communication (Time slots $N = 1, 2$ or 8)
- Communication path between relays
 - Residence time of all communication nodes (e.g., SDH multiplexers, MPLS routers)
 - Propagation delay of all communication links (e.g., optical fibers)
 - Speed of the communication links (e.g. 1 Gbit/s, 10 Gbit/s)

In case of Circuit emulation (e.g., with SAToP, CESoPSN) over MPLS:

- At the ingress MPLS router: Packet payload size (number of C37.94 timeslots per MPLS packet, usually configurable)
- At the egress MPLS router: De-jitter buffer size (usually configurable)

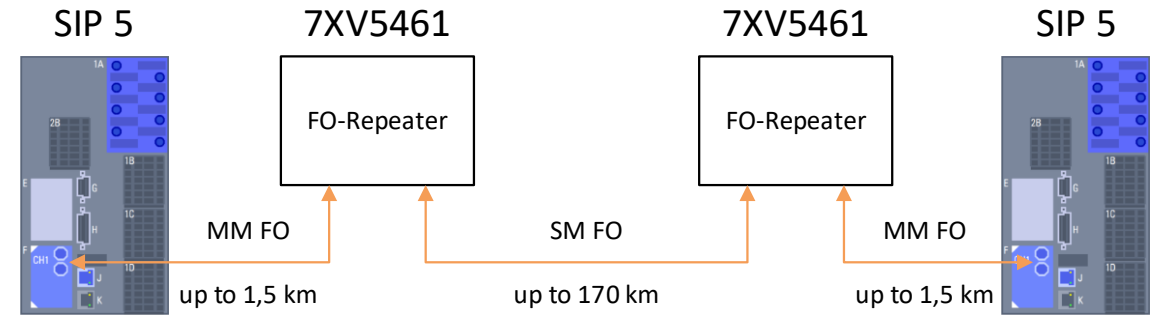
Communication Converters

Protection Interfaces and Communication Converters

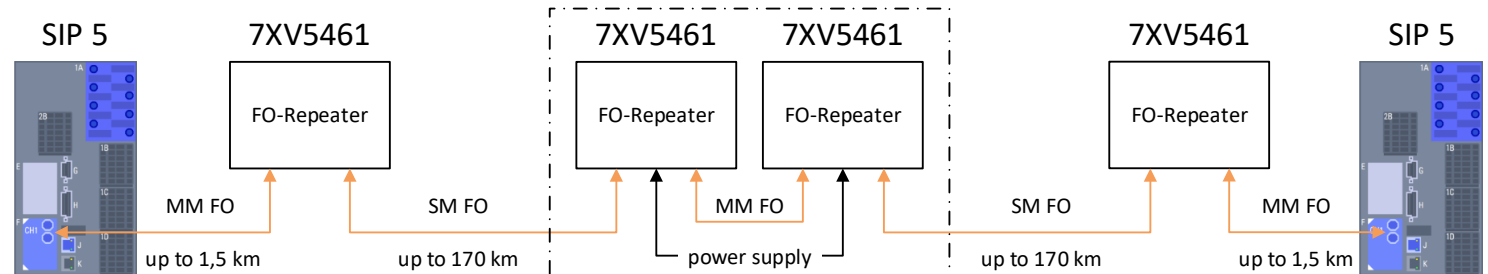
Direct fiber optic connection using repeaters

Fiber optic repeater

- 7XV5461-0Bx00 (x: order options)
- max. distance: 24 km / 60 km / 100 km / 170 km
- Multiplexing port 1 and 2 into port 3
- Transparent data transmission (no framing)
- Up to 2 Mbit/s (FM0 / Manchester coding)



very long FO distance application:



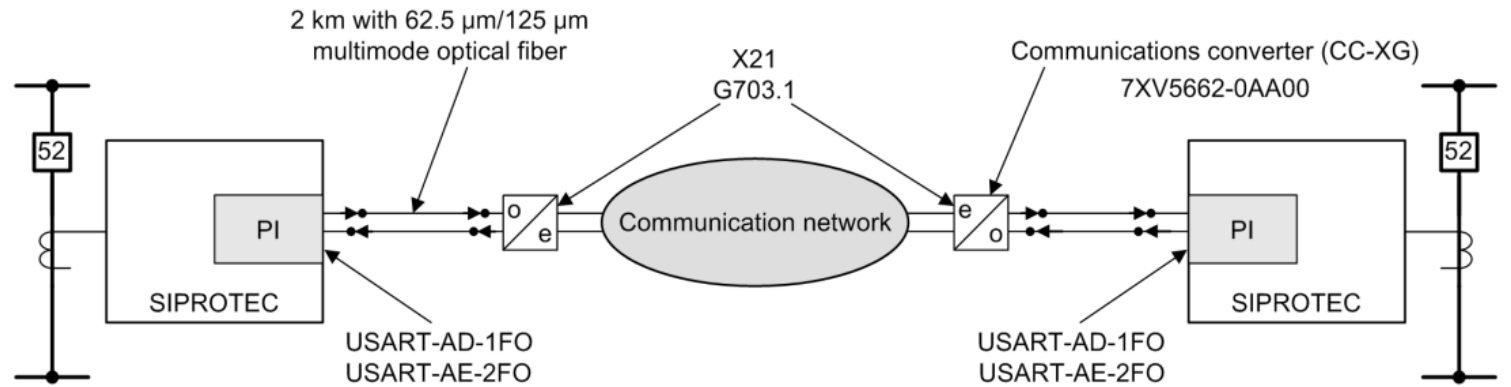
Protection Interfaces and Communication Converters

Communication converter for X.21/G.703.1

Communication converter – CC-XG

- 7XV5662-0AA00
- Synchronous and asynchronous
- Interface X.21
 - (64, 128, 256 or 512) kBit/s
- Interface G.703.1
 - 64 kBit/s

- ST, 820 nm, HDLC interface for SIP 4 / SIP 5
- Selection of data interchange via pushbutton
- Life contact

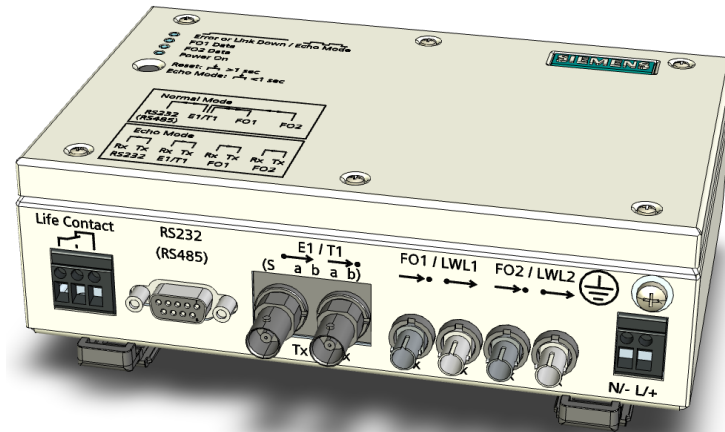
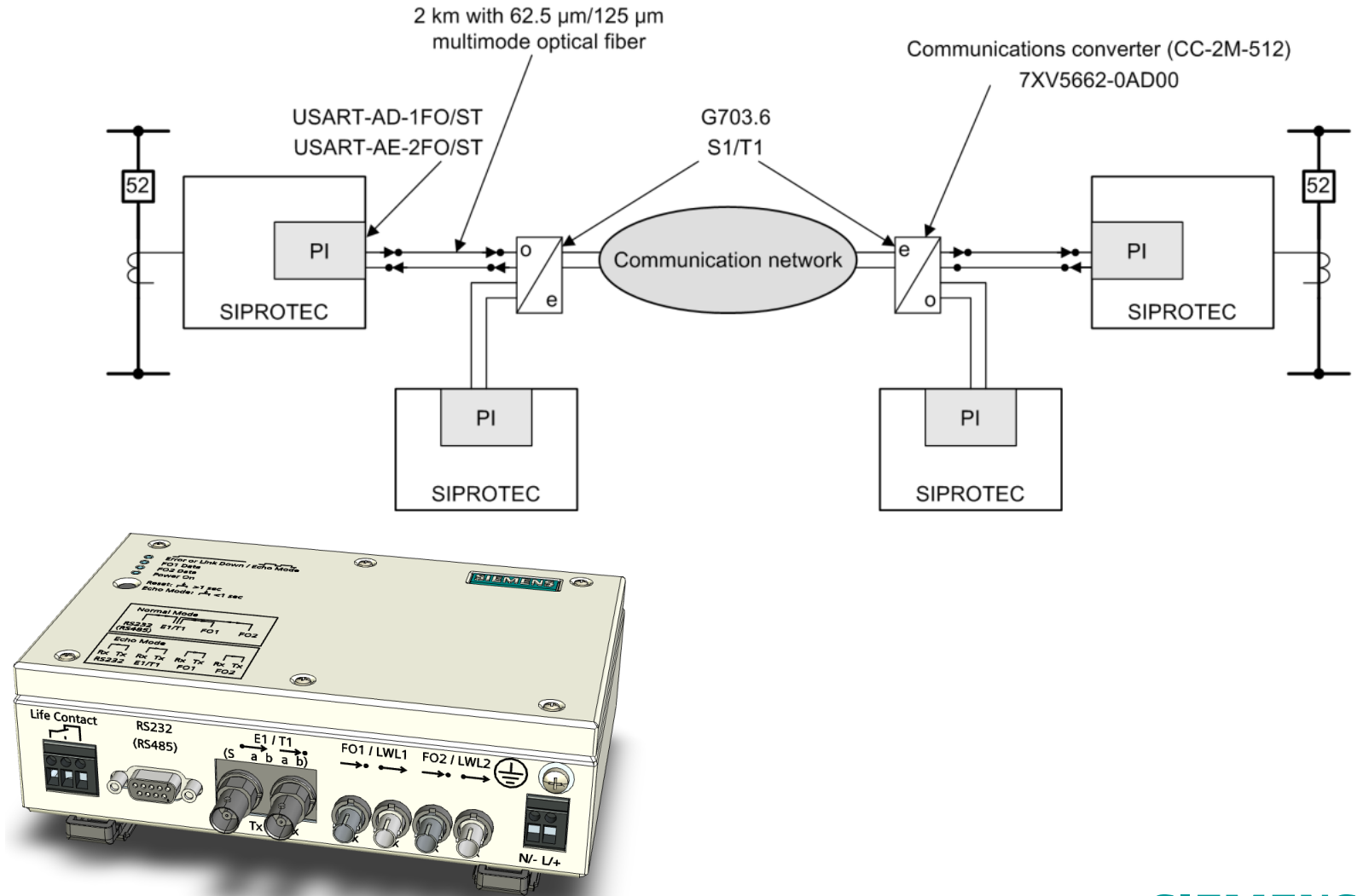


Protection Interfaces and Communication Converters

Communication converter for E1/T1

Communication converter – CC-2M

- 7XV5662-0AD00
- Synchronous: 512 kBit/s
- Asynchronous: up to 115.2 kBaud
- Multiplexing 2x FO into E1/T1
- E1/T1: BNC or 5 pin



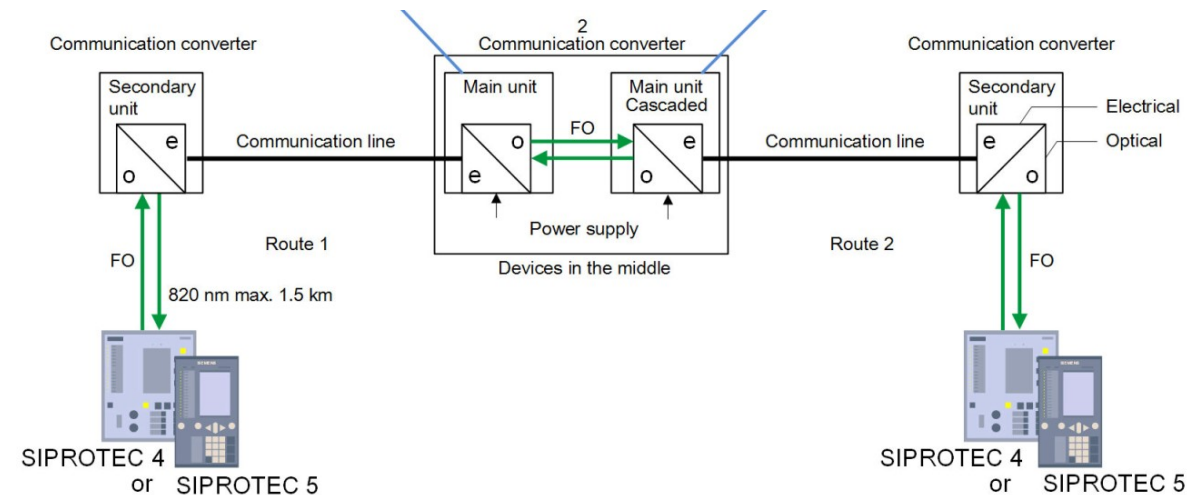
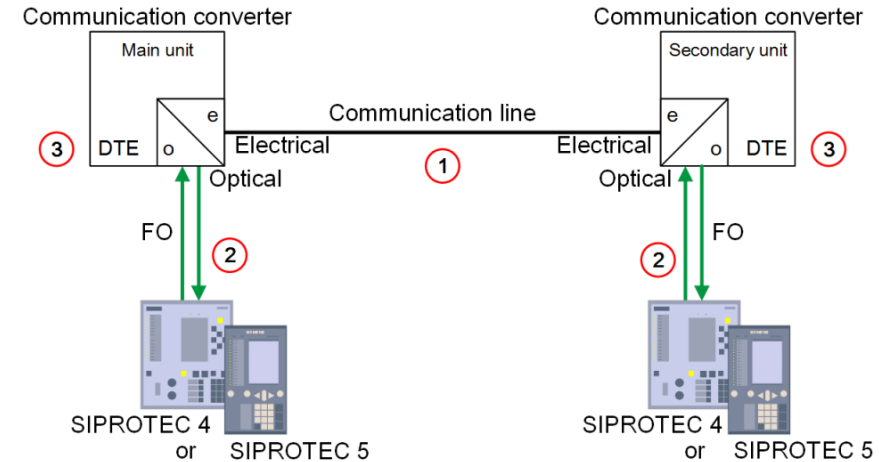
Protection Interfaces and Communication Converters

Communication converter for Pilot wire

Communication converter – copper (CC-CO)

- 7XV5662-0AC02
- Pilot wire SHDSL communication
- Up to 12 km (20 km in cascaded operation)
- 5 kV isolation voltage
- **128 kBit/s ... 2048 kBit/s**,
- Configuration via few jumpers

- SIPROTEC 4 with FO5 module
 - 7SD52, 7SD610, 7SA52 and 7SA6
- SIPROTEC 5 with USART-AD-1FO or USART-AE-2FO
 - 7SD8, 7SA8, 7SL8, 7UT8, 7SX8



Protection Interfaces and Communication Converters

Pilot wire communication

- Electrical, long distance, data transmission using ISDN (older: 7XV5662-0AC00) or SHDSL technology
 - Pair of communication cables → telephone line, “pilot wire”
 - Max. distance approx. 12 km
- Risk of high voltage induction due to parallel laid power lines, earth fault
- Monitoring of pilot wire is needed → Line Diff. block in case to failures

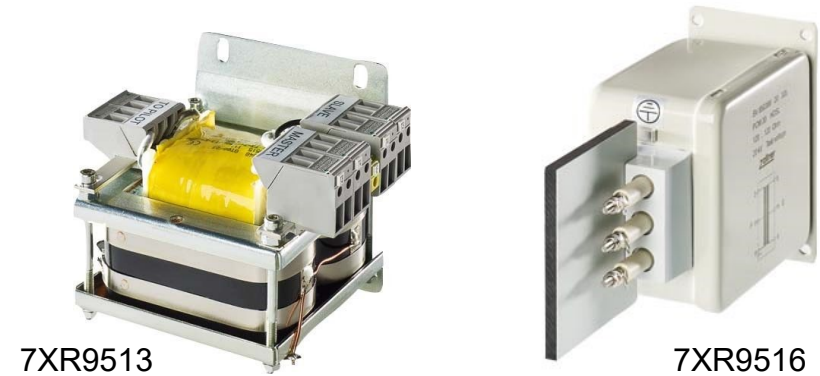
- Accessories

- Isolation transformers

- 7XR9513, 7XR9516 20 kV
 - 7XR9514, 7XR9515 5 kV
 - C53207-A406-D195-1 6 kV

- Communication converter Copper (FO 820 nm ↔ pilot wire)

- 5 kV isolation voltage

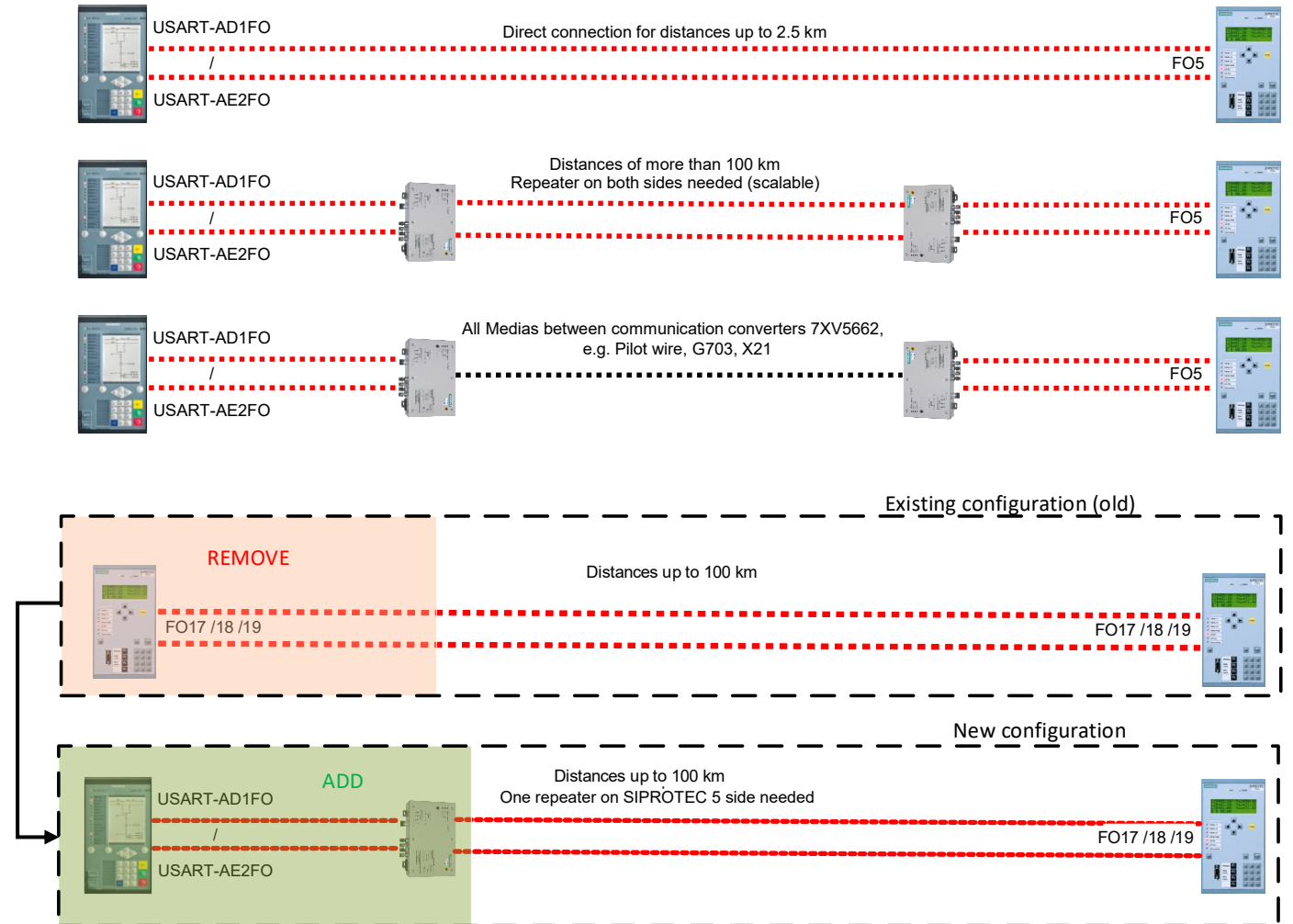


Combination of SIPROTEC 4 and SIPROTEC 5 Devices in the Same Topology

- Compatibility of Line Differential devices
- Retrofit applications
- CT error settings slightly higher:

Transformer Class	Parameter			
	SIPROTEC 4 (253) E% ALF/ ALF_N	SIPROTEC 5 (_:8881:108) CT error A	SIPROTEC 4 (254) E% K_ALF_N	SIPROTEC 5 (_:8881:109) CT error B
5P	3.0 %			12 %
10P	5.0 %			21 %
TPX	1.0 %			21 %
TPY	3.0 %			21 %
TPZ	6.0 %			28 %
PX	3.0 %			12 %
C100 to C800	5.0 %			21 %

- For long distance FO applications additional optical repeater required
- LD FO modules in SIP 5 use different framing than FO 17/18/19

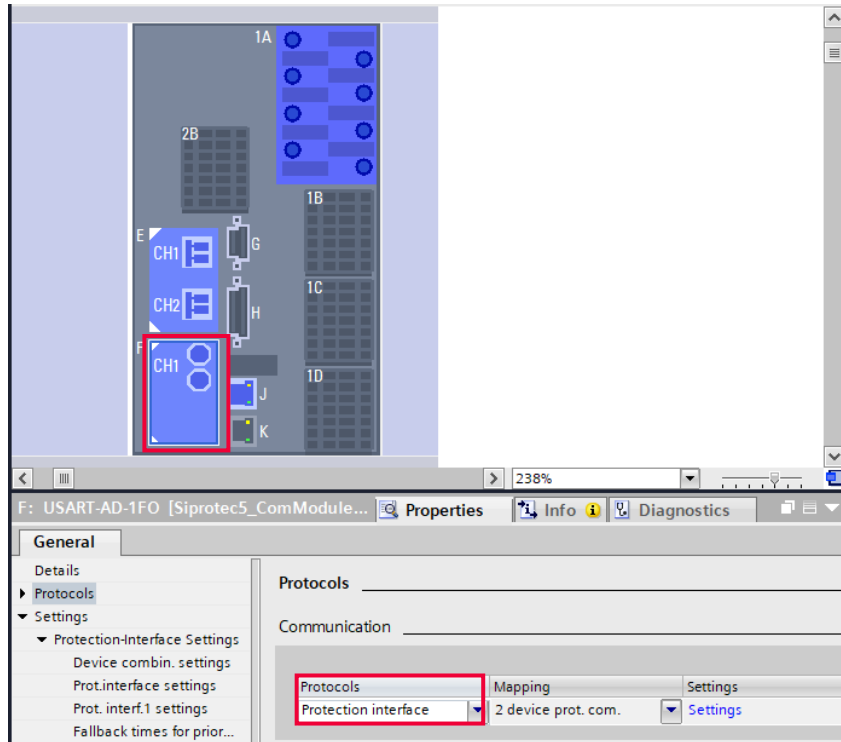


Advanced versus Classic Protection Interface

Advanced vs. Classic Protection Interface

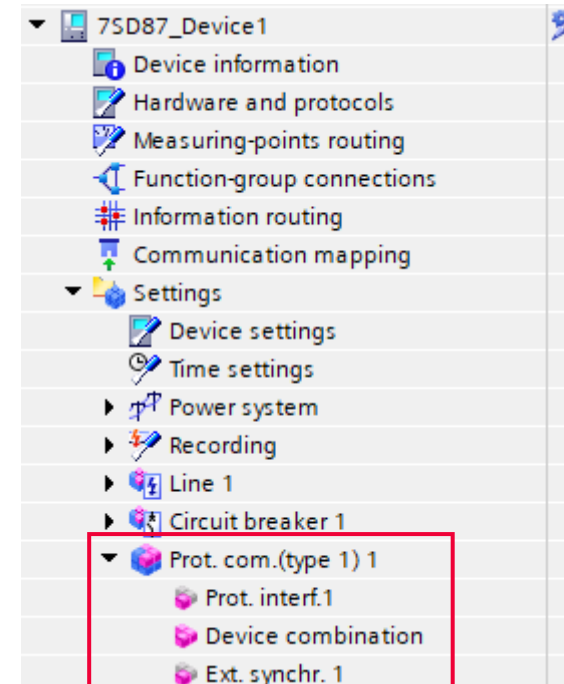
New Workflow in DIGSI 5 since Firmware V08.60

Classic Protection Interface



→ All settings are made in the properties tab of the communication module

Advanced Protection Interface



New function group (FG) in the object oriented structure
→ Settings are made within the FG Prot. Com.

Advanced Protection Interface

- Configuration of the advanced protection interface is available for:
 - ETH-BD module (Diff. over IP)
 - USART modules
- Both workflows can be used within the same device for different PI modules
- Compatibility of differential protection communication between devices with new and old workflow
 - New workflow supports remote device running an older firmware < V08.60
- SIPROTEC 4 compatibility fully supported
- Multi-ended line protection
 - Pricing is based on Function points (FP) instead of the “significant feature” (SF)
 - Function point manager supports the conversion/downgrade of SF → equivalent FP

Advanced Protection Interface

Benefits



- More flexibility in the functional scope of a device
- Diff over IP possible
- Multiplexed operation of PI possible
- Phase rotation possible (special applications)
- Up to three FG “Line” with line differential protection 87L each

Advanced Protection Interface

Multiplexed operation for special applications

(1)

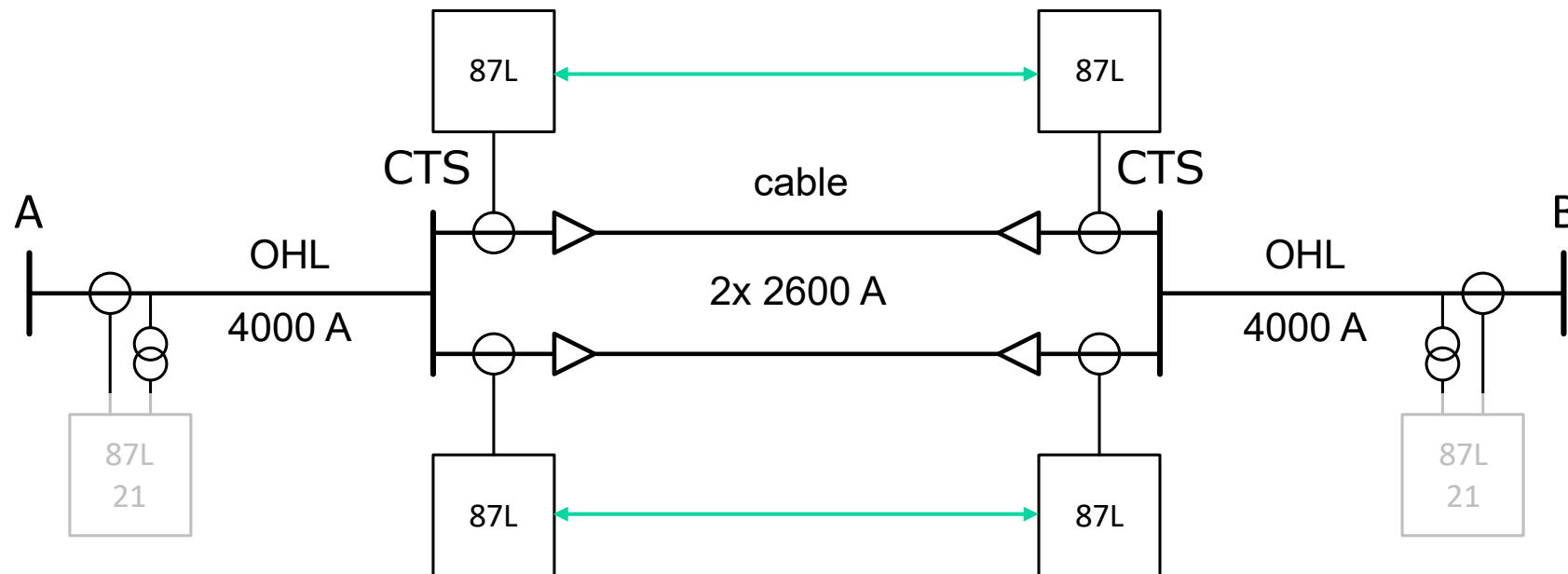
Application example: Hybrid lines (mixed OHL and cable sections)

- Cable transition stations (CTS)

Protection of parallel HV cables



Source: TSO Amprion



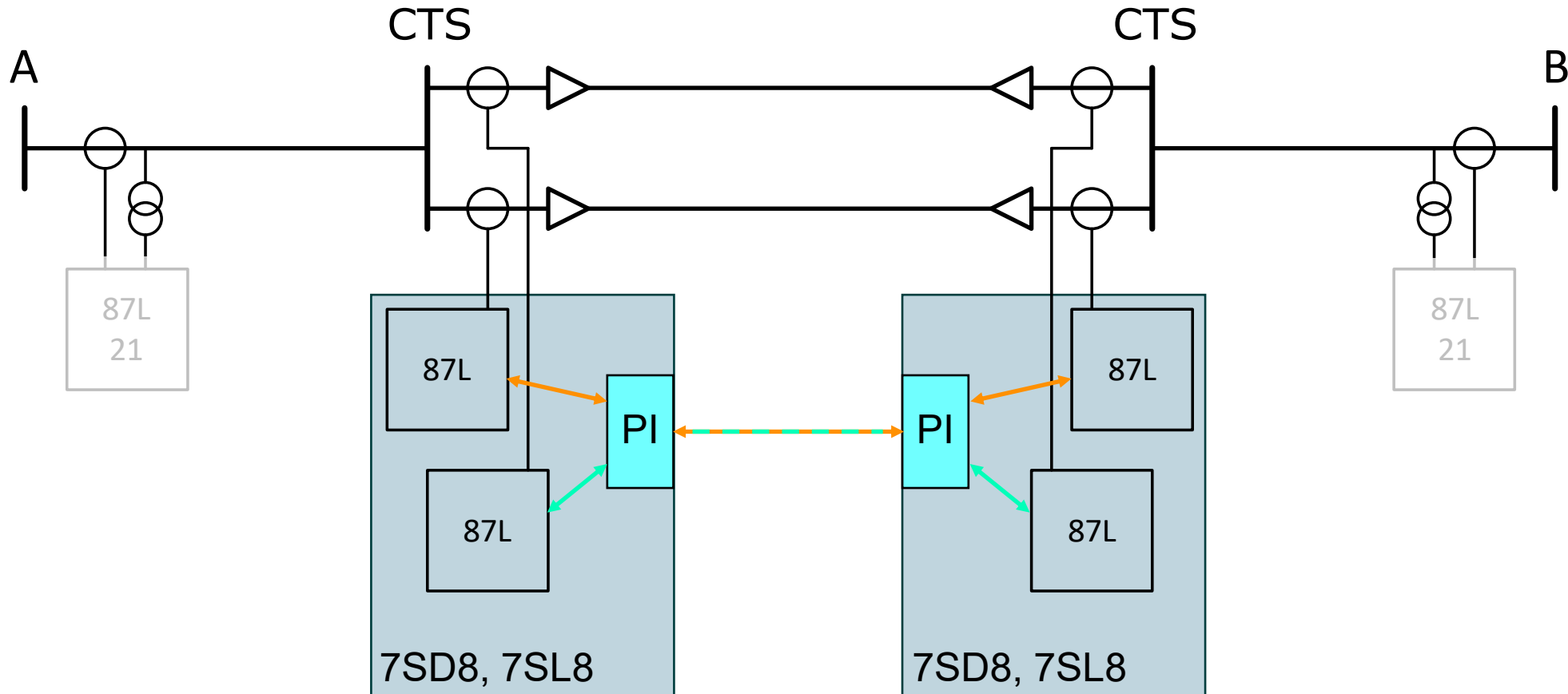
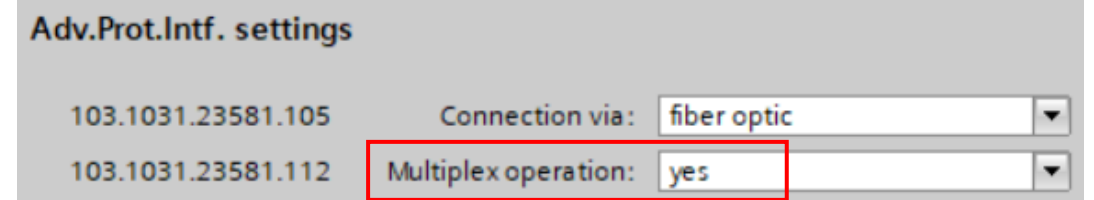
Advanced Protection Interface

Multiplexed operation for special applications

(2)

Multiplexed operation of single Protection interface (PI)

- 2 MBit/s bandwidth required (2x 512 kBit/s; e.g. direct FO)

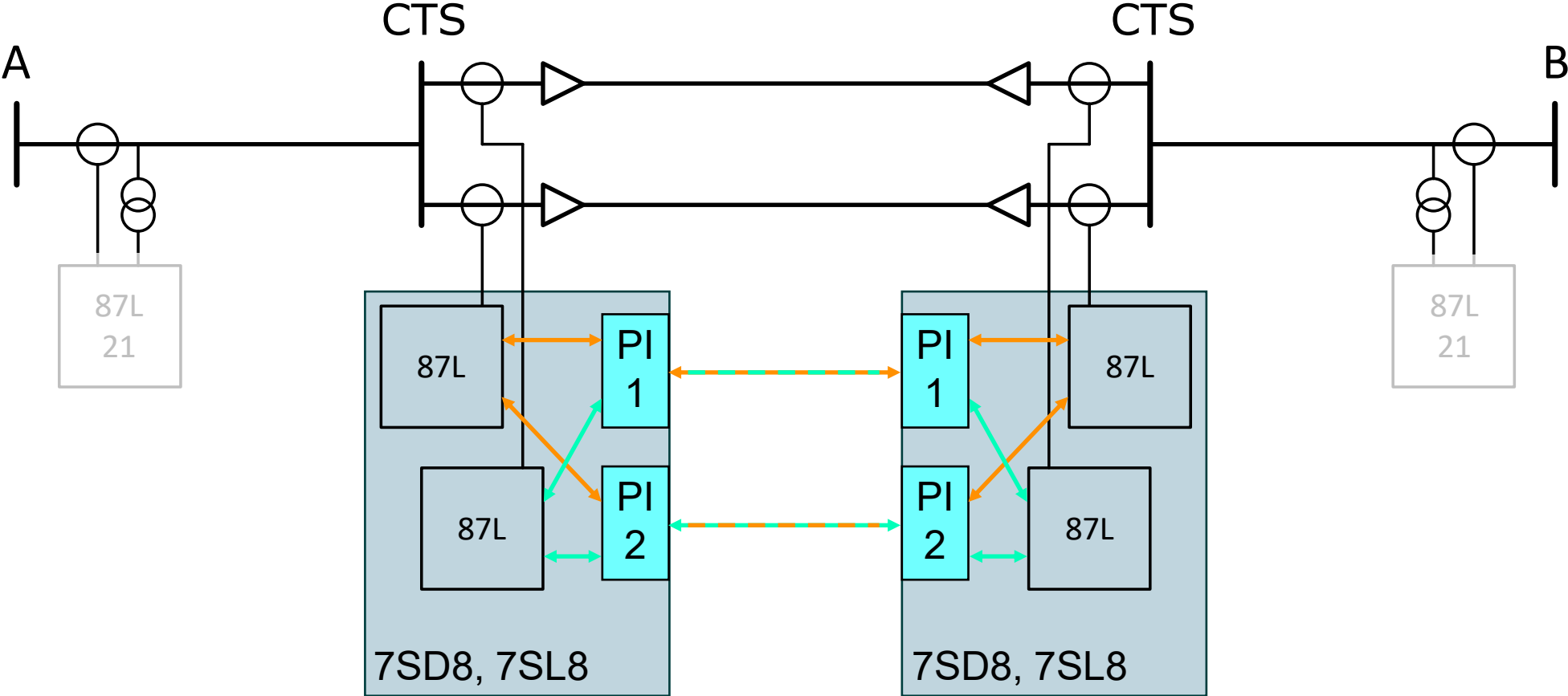


Advanced Protection Interface

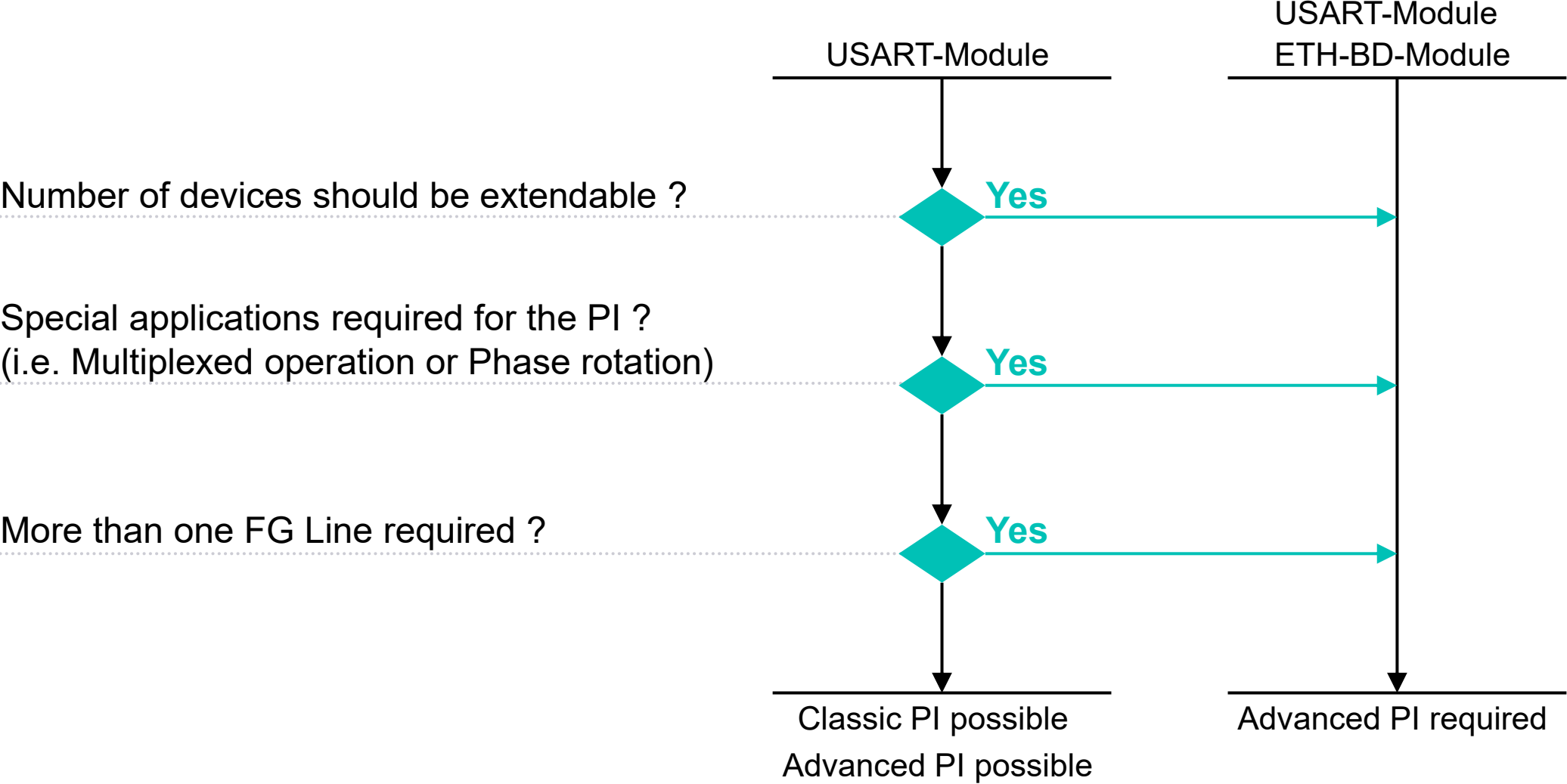
Multiplexed operation for special applications

(3)

Redundant multiplexed operation of two Protection interfaces (PI)

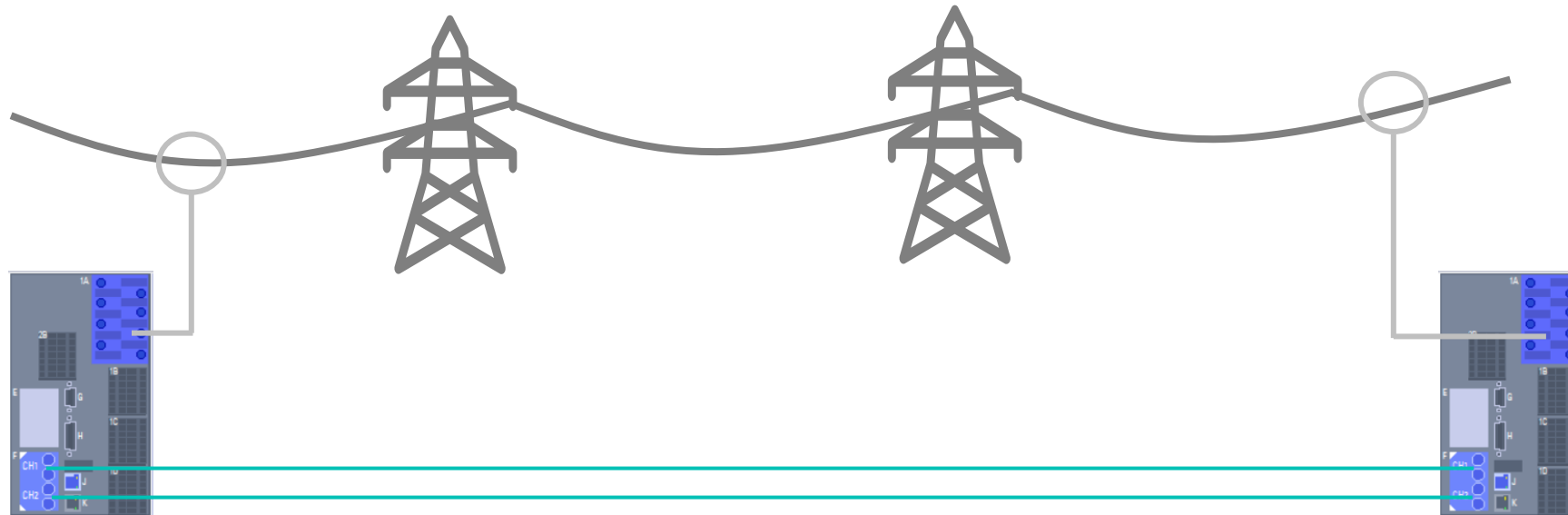


Advanced Protection Interface Decision Matrix

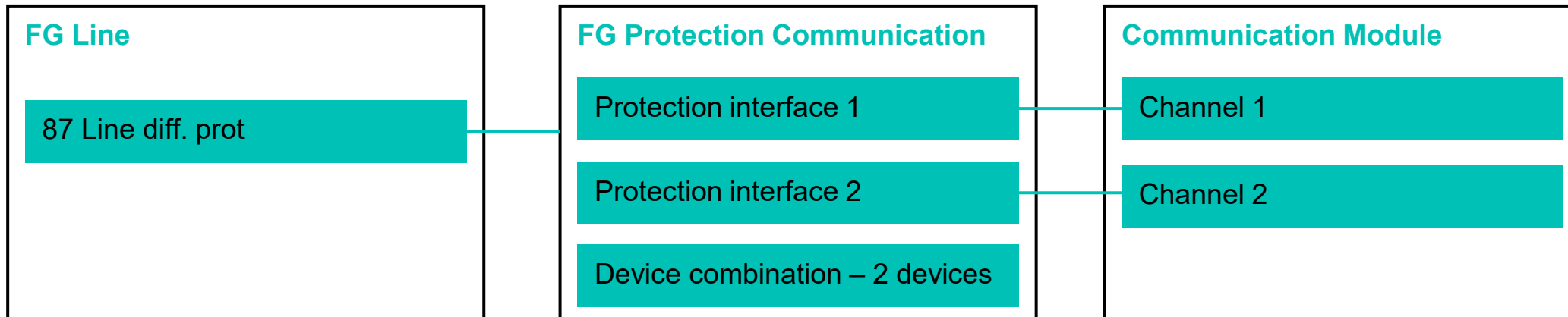


Advanced Protection Interface DIGSI 5 Demo

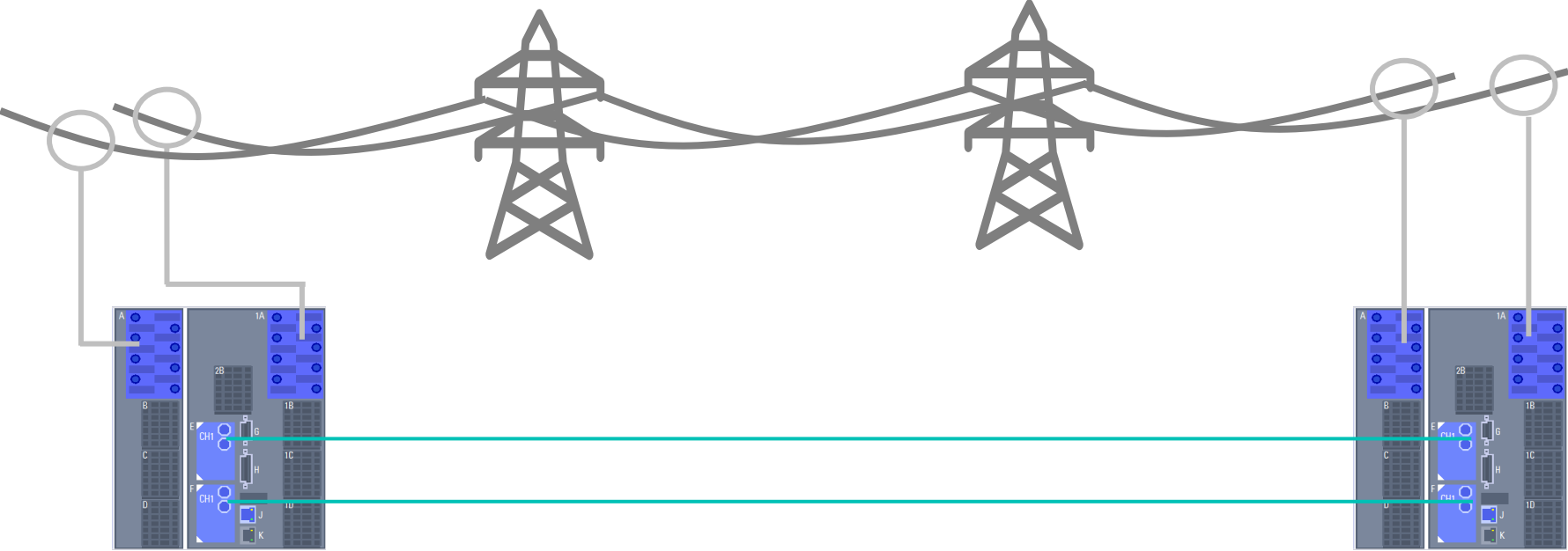
2 End Protection: Redundant Communication



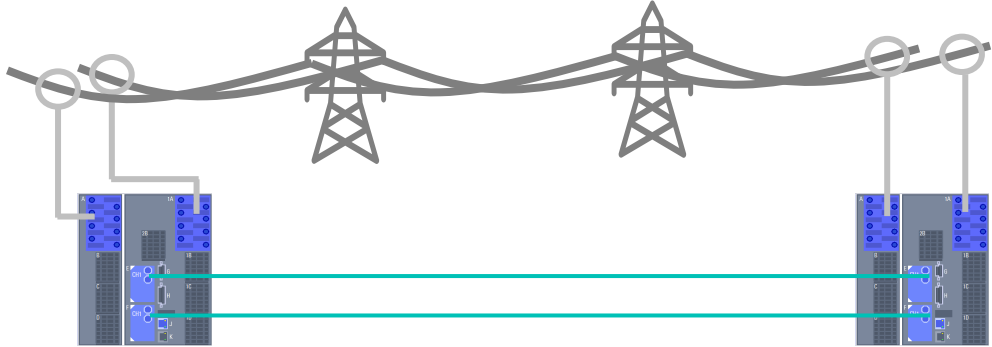
2 End Protection: Redundant Communication



Parallel Lines: Multiplexer Operation, Redundant Communication



Parallel Lines: Multiplexer Operation, Redundant Communication



FG Line

87 Line diff. prot

FG Protection communication 1

Protection interface 1, 2

Device combination – 2 devices

Communication module 1

Channel 1

FG Line

87 Line diff. prot

FG Protection communication 2

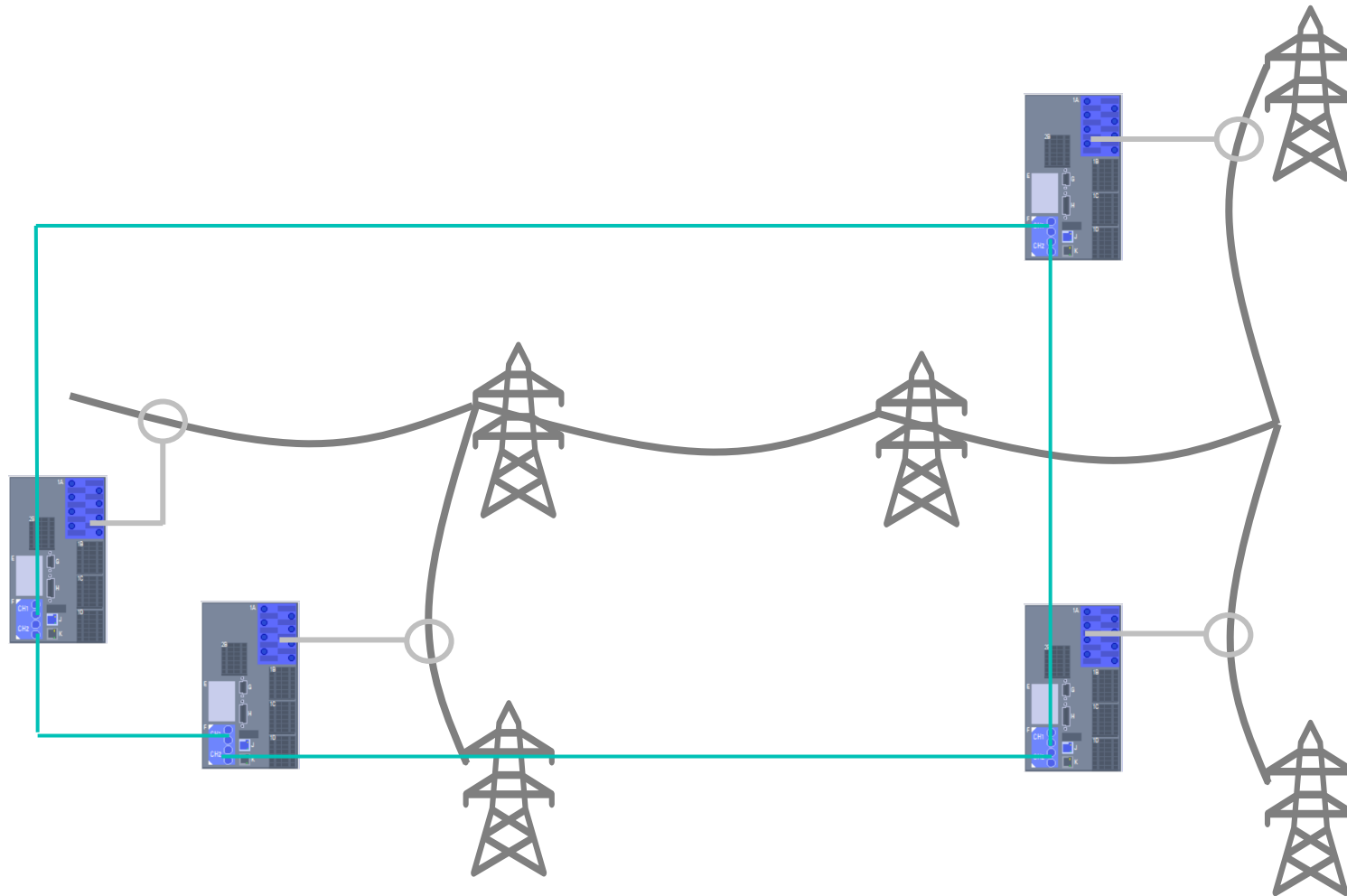
Protection interface 1, 2

Device combination – 2 devices

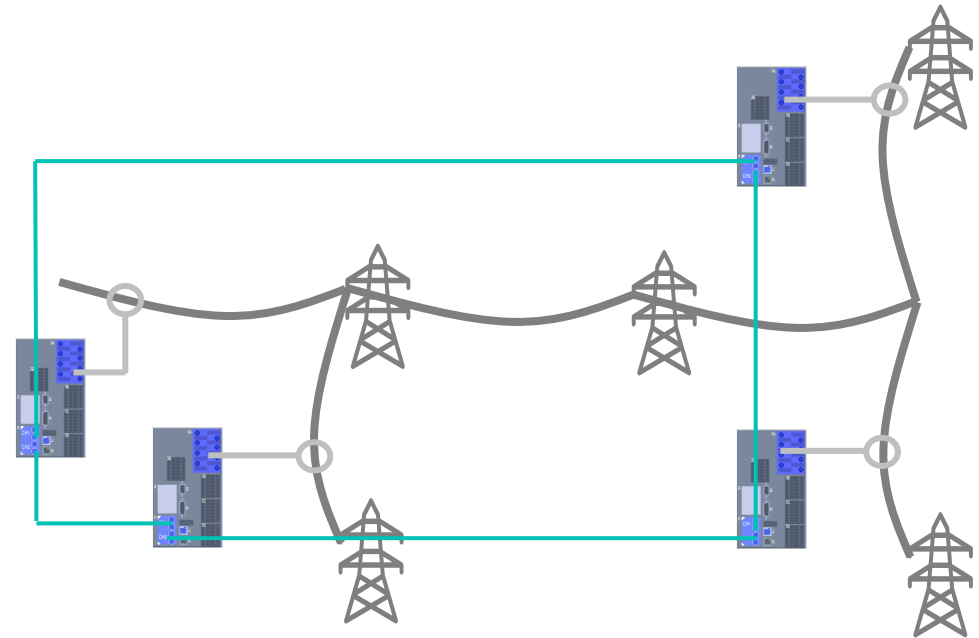
Communication module 2

Channel 1

4 End Protection: Ring Topology



4 End Protection: Ring Topology



FG Line

87 Line diff. prot

FG Protection Communication

Protection interface 1

Protection interface 2

Device combination – 4 devices

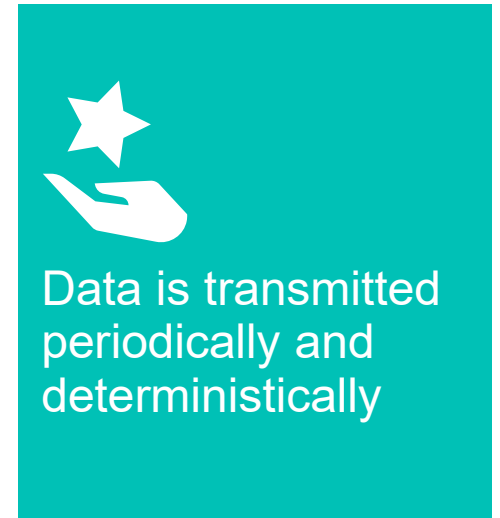
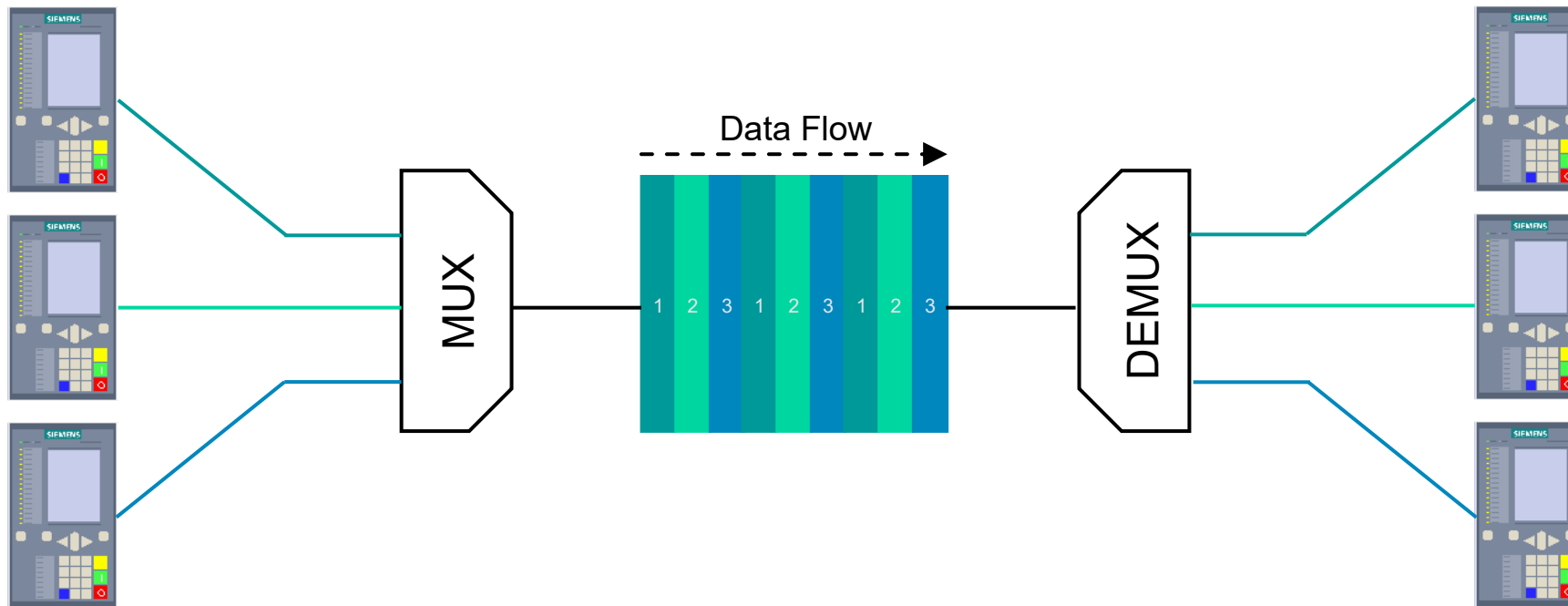
Communication Module

Channel 1

Channel 2

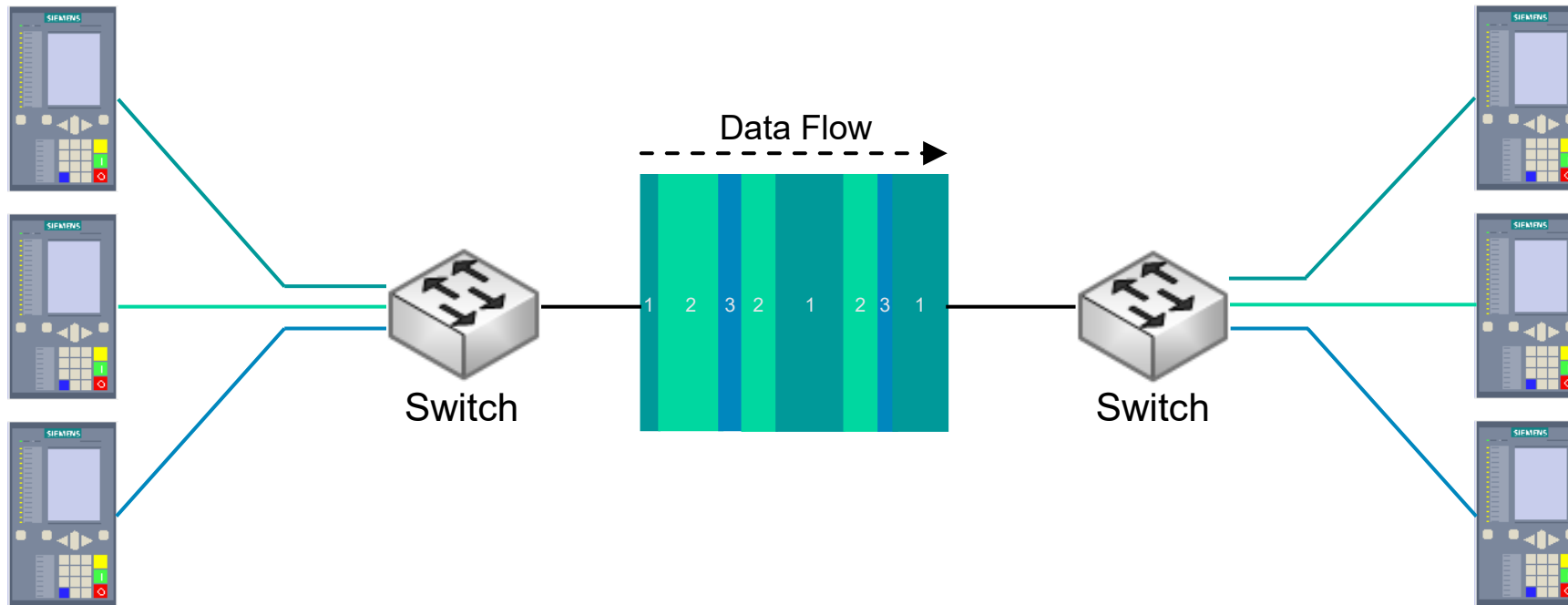
Line Differential Protection over IP/Ethernet

Legacy technology: Time Division Multiplexing (TDM)



- A constant amount of bandwidth is assigned to each device
 - Each device can transmit a pre-defined amount of data at a specific point in time
 - Technology for telephone networks running at 64 kBit/s (8 Bit x 8 kHz sampling)

Today's technology: Packet Switched Network (PSN)



- Transmits data in the form of packets → Each participating device can send packets at any time
- If several packets arrive at a network device at the same time, these packets are stored in a memory and are processed according to the “first come – first served” FIFO principle

Transition from TDM networks (SDH/SONET) to packet based networks

Line Differential over MPLS with Channel Emulation

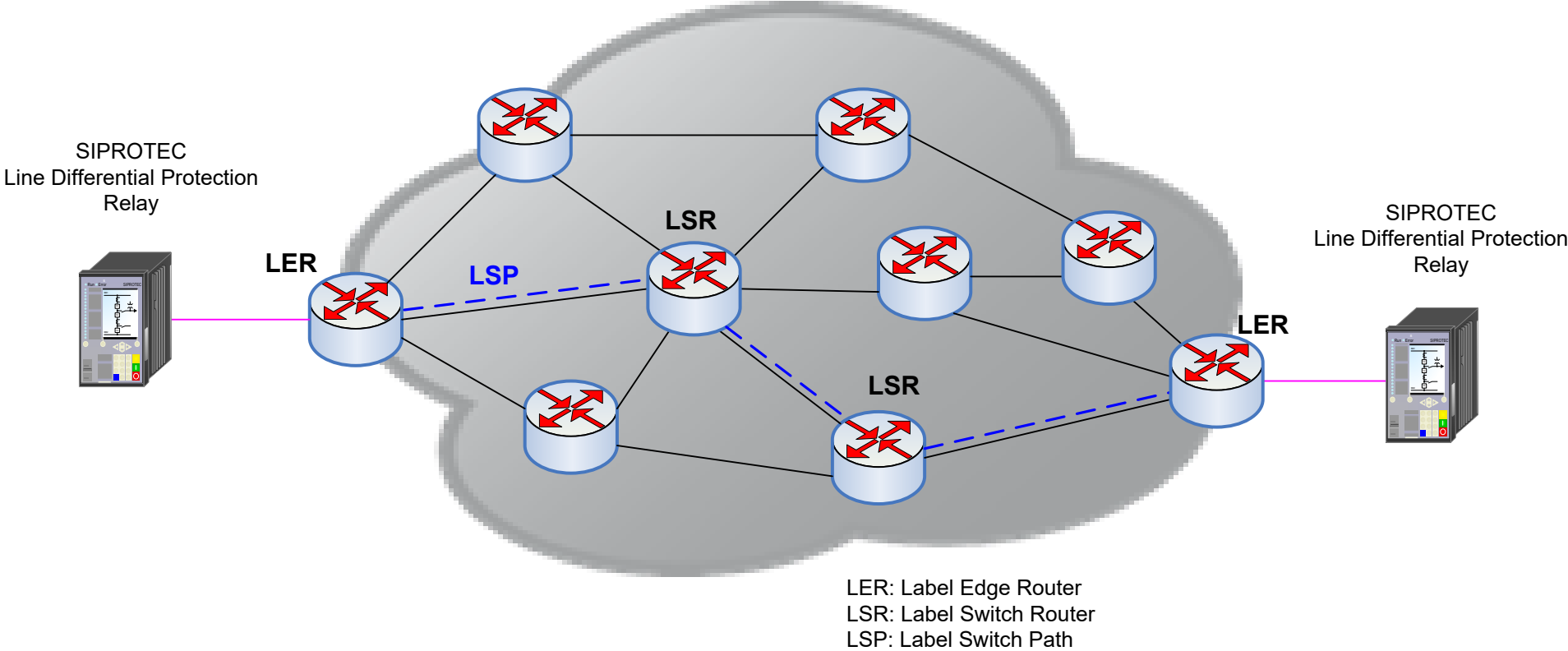
- MPLS (Multiprotocol Label Switching)
 - IP/MPLS
 - MPLS-TP
- E1/T1 circuit emulation modes for packet-switched networks → “pseudowire”
 - RFC 4553: Structure-Agnostic Time Division Multiplexing (TDM) over Packet (SAToP)
 - Bitwise transport of TDM signal → “transparent” mode
 - Circuit Emulation Service over Packet-Switched Network (CESoPSN)
 - Decode TDM signal as N x 64 kBit/s → transport

Protection Interfaces

MPLS Communication Network

Line differential protection communication via MPLS network

- Pseudowire (co-routed bidirectional label switched routers)

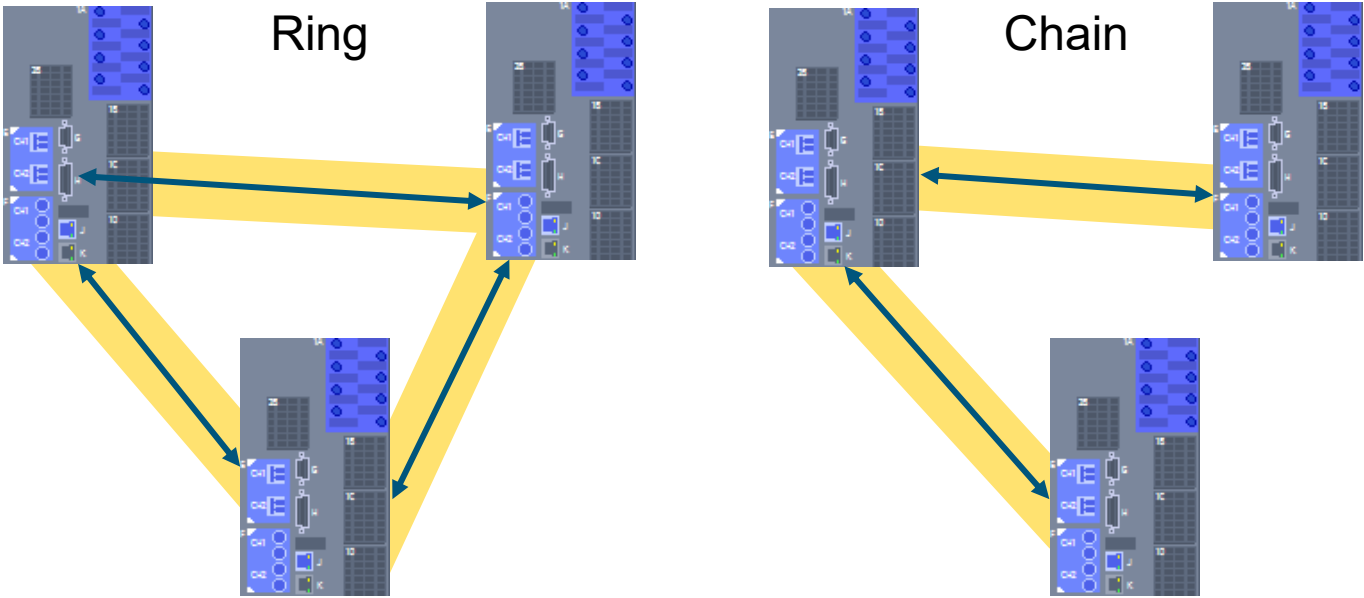


SIPROTEC 5 Protection Relay Communication

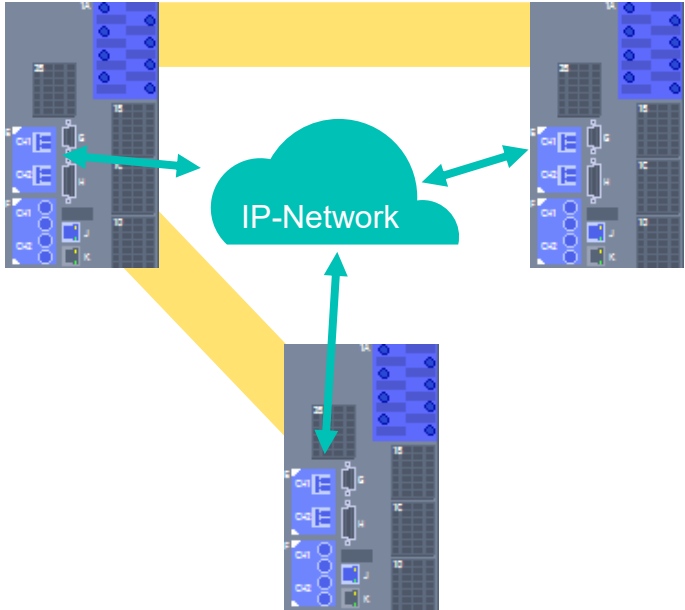
New IP-Based Communication



- Line differential protection communication uses a Siemens-proprietary application layer protocol
- Hop-by-hop communication in ring or chain topology

Serial Communication Modules (USART)



New: IP-Based

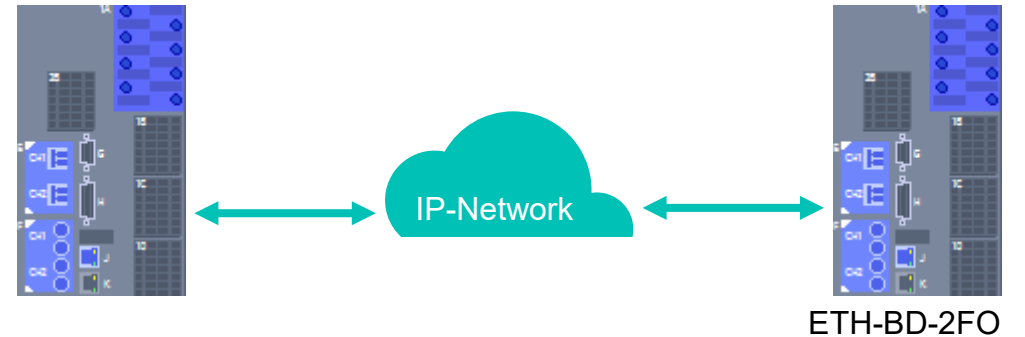


 Protection Interface Application
 Communication medium

 IP/Ethernet

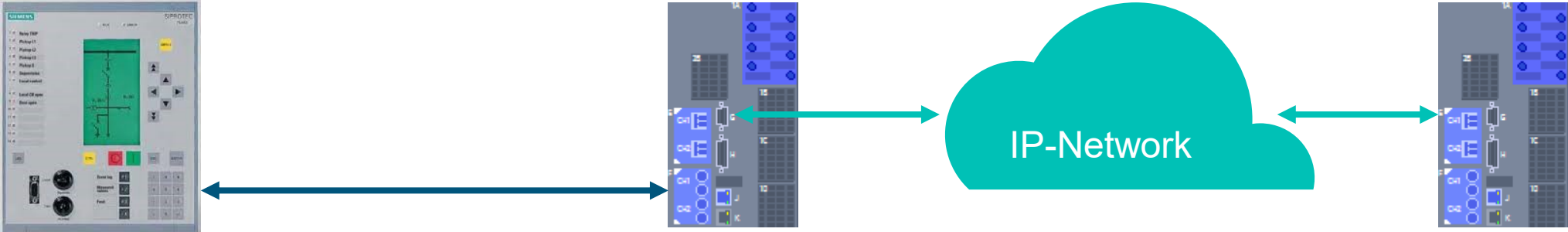
Line Differential over IP Networks

- Hardware requirements: SIPROTEC 5 modular device, with a ETH-BD-2FO module
- Software requirements: Firmware \geq V08.60
- New communication protocol on the ETH-BD-2FO module
 - Protocol according to UDP/IPv4 standard
 - Suitable for MPLS-TP, MPLS-TE, WAN, Ethernet...
- Supports IEEE 1588 PTP running on the same module
- External synchronization needed !
(IEEE 1588, PTP or 1PPS)
- Direct connection to communication networks
(via routers or switches) without expensive line-cards or similar



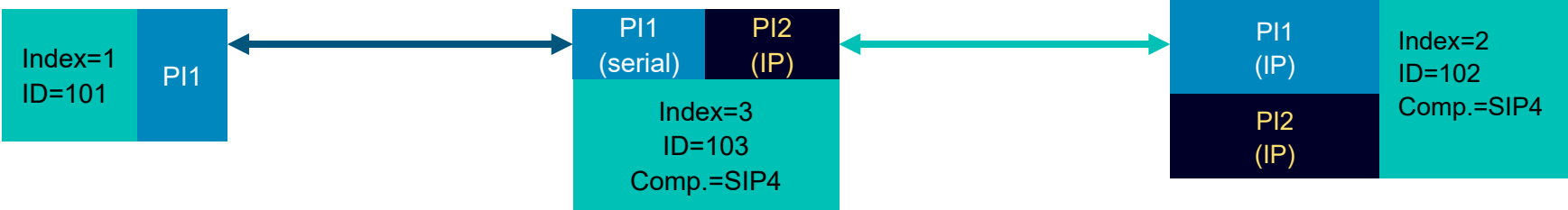
Advanced Protection Interface Application

Mixed 3 device chain with SIPROTEC 4 device



Physical

Logical



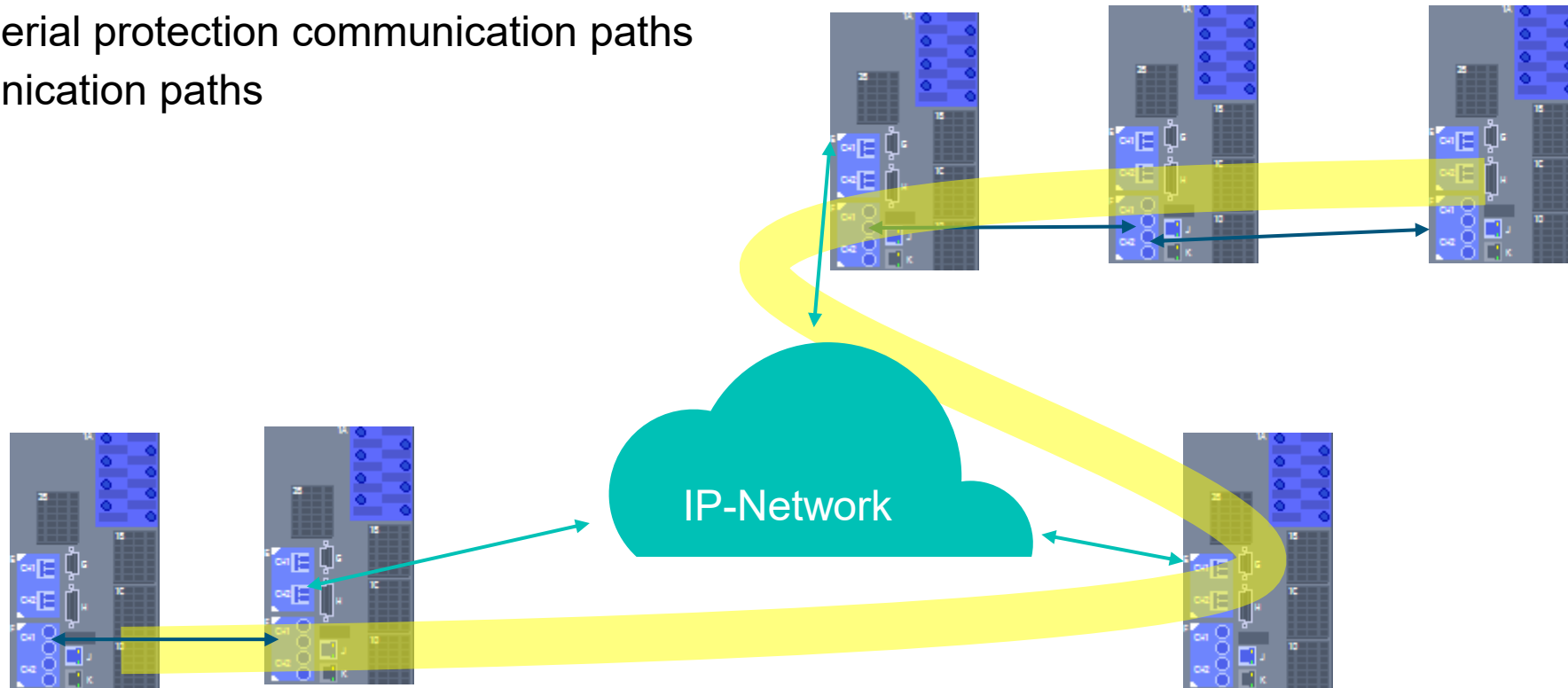
Communication medium
 IP/Ethernet

Advanced Protection Communication

SIPROTEC 5 – Platform (V8.60)

Differential-/Protection communication via IP-based Networks:

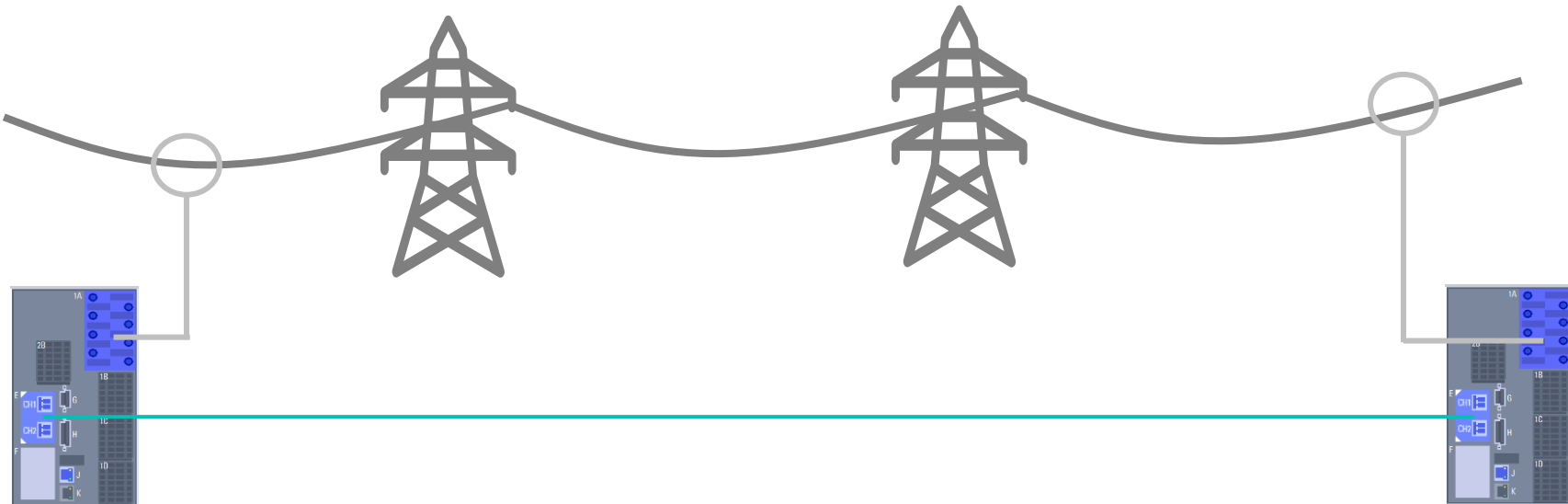
- Mixed topologies possible:
 - Classical serial protection communication paths
 - IP-Communication paths



Line Diff. over IP DIGSI 5 Demo

2 End Protection

Diff over IP



FG Line

87 Line diff. prot

FG Protection Communication

Protection interface 1

External Synchronization

Device combination – 2 devices

Communication Module

Channel 1

Line Differential Protection webinar series

Links to all webinars of the series

- **Part 1: Line Differential Protection - Basics**
<https://smartinfrastucture.webinar.siemens.com/line-differential-protection-part/b1f36e4f86751bac5b5b>
- **Part 2: Line Differential Protection - Interfaces**
<https://smartinfrastucture.webinar.siemens.com/line-differential-protection-part-1/5101ce29a70e0f2f0c95>
- **Part 3: Line Differential Protection - Configuration and Testing**
<https://smartinfrastucture.webinar.siemens.com/line-differential-protection-part-2/a155d5a3afa6d0d61295>
- **Part 4: Line Differential Protection - Compatibility of SIPROTEC 4 and SIPROTEC 5**
<https://smartinfrastucture.webinar.siemens.com/line-differential-protection-part-3/a582c41832151fbce672>

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