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PowerLink IP

The power line carrier solution for digital transmission grids

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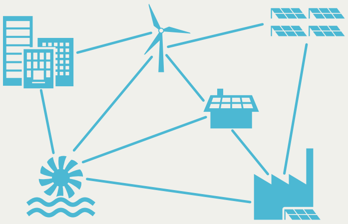
New challenges for operators of high-voltage networks

The deregulation of energy markets and rapidly growing decentralized power generation are making the management of power networks more complex. In addition, the rapid growth of network digitalization is leading to an increasing demand for data communication. The new Siemens PowerLink IP provides an attractive and economical solution to these challenges.



In traditional high-voltage (HV) substations, applications like binary teleprotection signals, control center commands, and analog voice only need low bit rates.

In contrast, the new digital HV substations use packet-based broadband communication infrastructure. In addition, new central data analytics and application services demand extended data bandwidth.

PowerLink IP – the power line carrier (PLC) solution for digital transmission grids

PLC systems utilize the high-voltage line(s) between transformer substations as an economical communication path for data, teleprotection, and voice.

Siemens power line carrier technology has been in use for decades and delivers extremely high standards of transmission reliability in network protection (for example, protection signals), safeguards transmission quality, and can be easily integrated into a wide range of communication networks.

PowerLink IP was designed for Ethernet/IP environments in the new digital high-voltage substations, making PLC systems more attractive and efficient than ever before.

PowerLink IP – your advantages at a glance

- PowerLink IP provides proven PLC technology for the extended bandwidth requirements of digital high-voltage substations
- Data rates of up to 2 Mbps for each transmission direction allow several traditional PLCs to be replaced
- The core feature is an expanded and more efficient bandwidth utilization
- The pure packet-based architecture reduces and simplifies installation and commissioning, maintenance effort, and training
- We offer tailor-made solutions for primary and backup HV substation interconnection
- PowerLink IP can be seamlessly integrated into existing PLC infrastructure
- It provides custom migration scenarios for integrating legacy devices
- Siemens product-related services support a smooth transition along the implementation path
- PowerLink IP is prepared for future software applications and is maintaining its role as a trendsetter in modern PLC technology – now and into the future

Rapid growth in the demand for communication

Traditional HV substation – limited bandwidth required

In traditional HV substations (Figure 1), grid control and remote access are the sole applications.

The substation is comprised primarily of a legacy communication infrastructure with serial and analog interfaces such as V.24, X.21, FXS, FXO, and E&M.

Most of the data consists of binary teleprotection signals, control center commands, and analog voice.

These applications require only narrowband bit rates and, for the most part, no integration into enterprise IT is required.

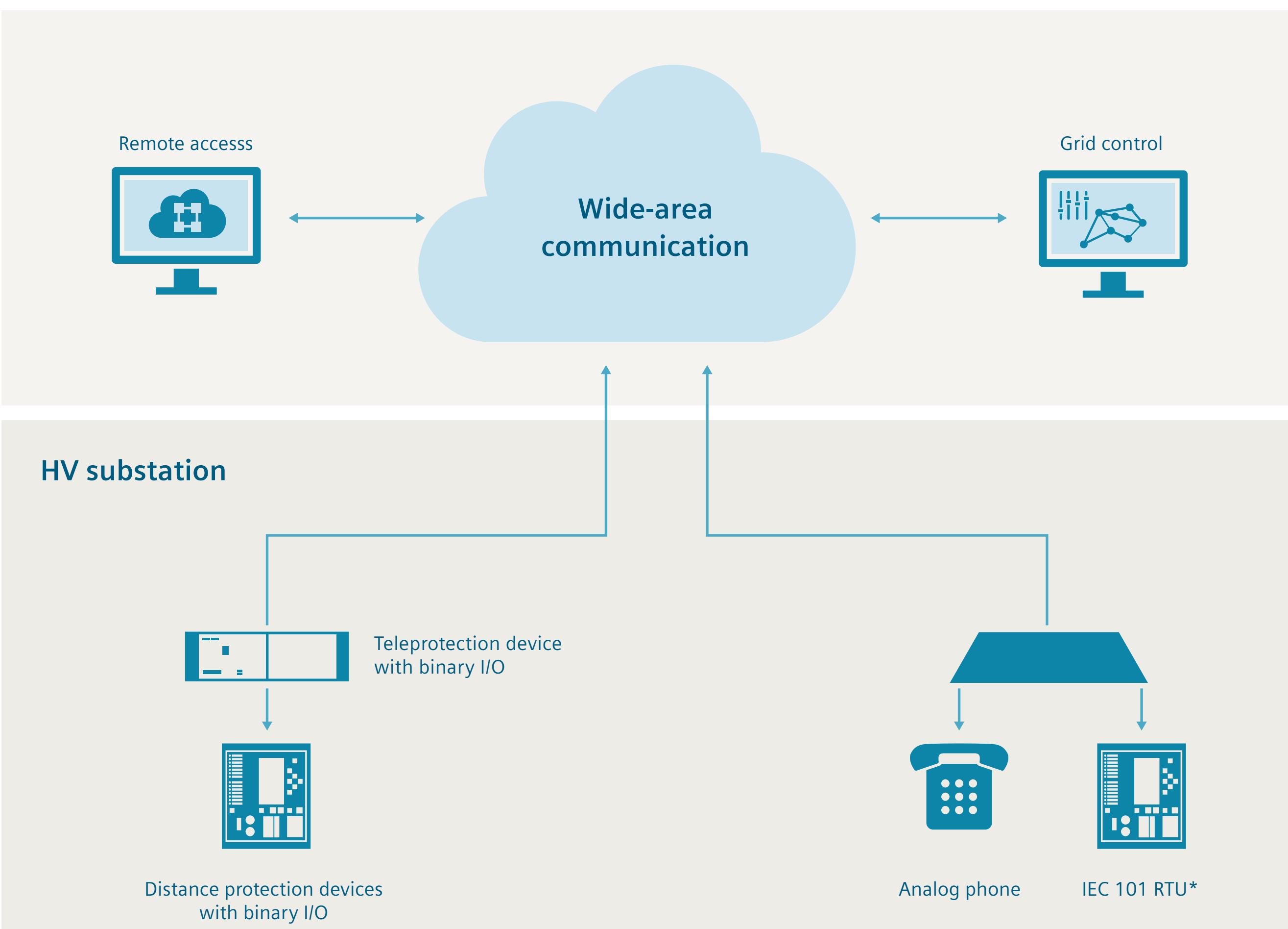


Figure 1: Traditional HV substation: limited demand for bandwidth

* IEC 60870-5-101

Digital HV substation – new applications need additional bandwidth

New central data analytics and application services as well as new substation devices like IEC 60870-5-104/IEC 61850 RTU, sensors/actors, PMU, fault/PQ recording, CCTV, and VoIP require more WAN bandwidth. These applications need IP and Ethernet as their main broadband communication infrastructure inside (LAN) and outside (WAN) the substation. The data flow is primarily asymmetrical, and cybersecurity is an integral feature.

Figure 2 shows a typical digital HV substation.

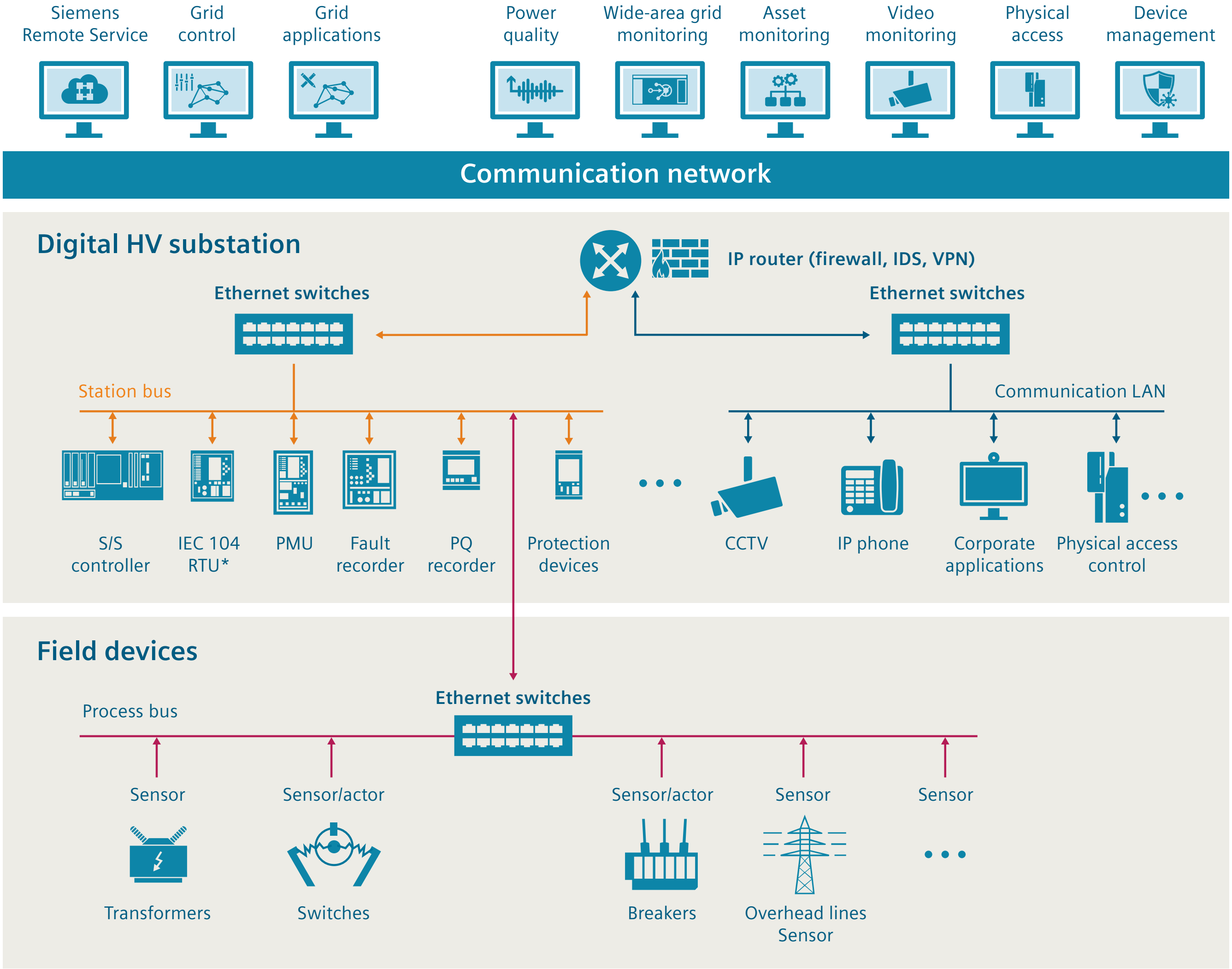


Figure 2: Digital HV substation: new applications need more bandwidth

* IEC 60870-5-104

The PowerLink IP system – optimized for Ethernet communication

System overview

The new PowerLink IP system has a pure packet-based architecture with a software-defined modem. It is optimized to fulfill the communication requirements of modern substation devices.

Figure 3 shows the system at a glance.

The digital modulation board contains an integrated L2 switch and provides six Ethernet interfaces. The LCT interface is intended for local administration, whereas the three electrical and two optical Ethernet interfaces are designed to connect substation devices.

System alarms can be displayed via alarm contacts or remote monitoring with the latest SNMP technology. The HV line interface transmits/receives the PLC signal and is connected to the coupling unit.

The integrated teleprotection system SWT 3000 provides binary I/O and GOOSE (IEC 61850) interfaces.

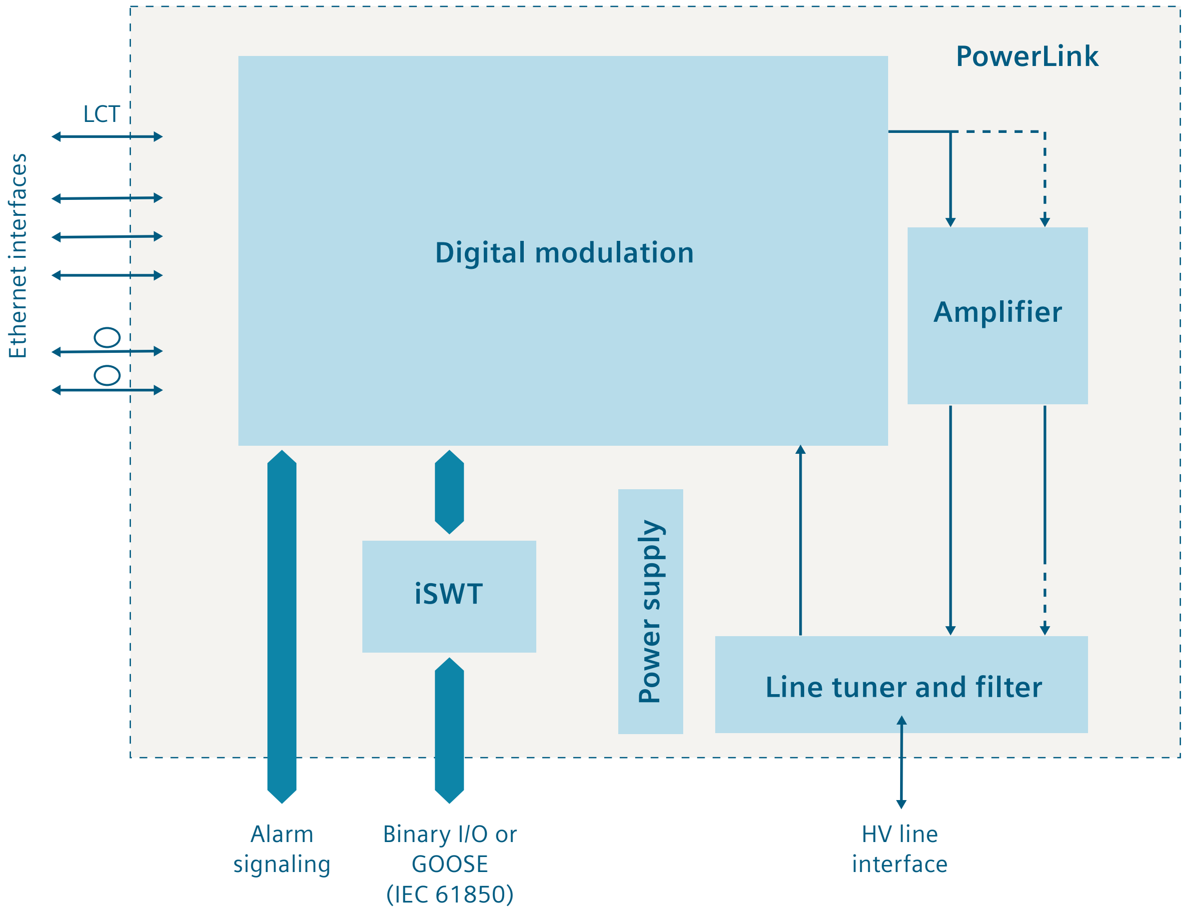


Figure 3: PowerLink IP: system architecture

Expanded channel bandwidth

HV power line carrier systems typically operate in the frequency range up to 500 kHz. Traditional HV-PLC systems use bandwidth up to 32 kHz per system, providing a data rate up to 320 Kbps.

In contrast to traditional PLC systems, PowerLink IP utilizes a frequency band of up to 256 kHz, allowing a maximum data rate of up to 2 Mbps[1] per transmission direction (see Figure 4).

Thanks to its expanded bandwidth, PowerLink IP can replace several traditional PLC systems.

[1] Specific set-up required

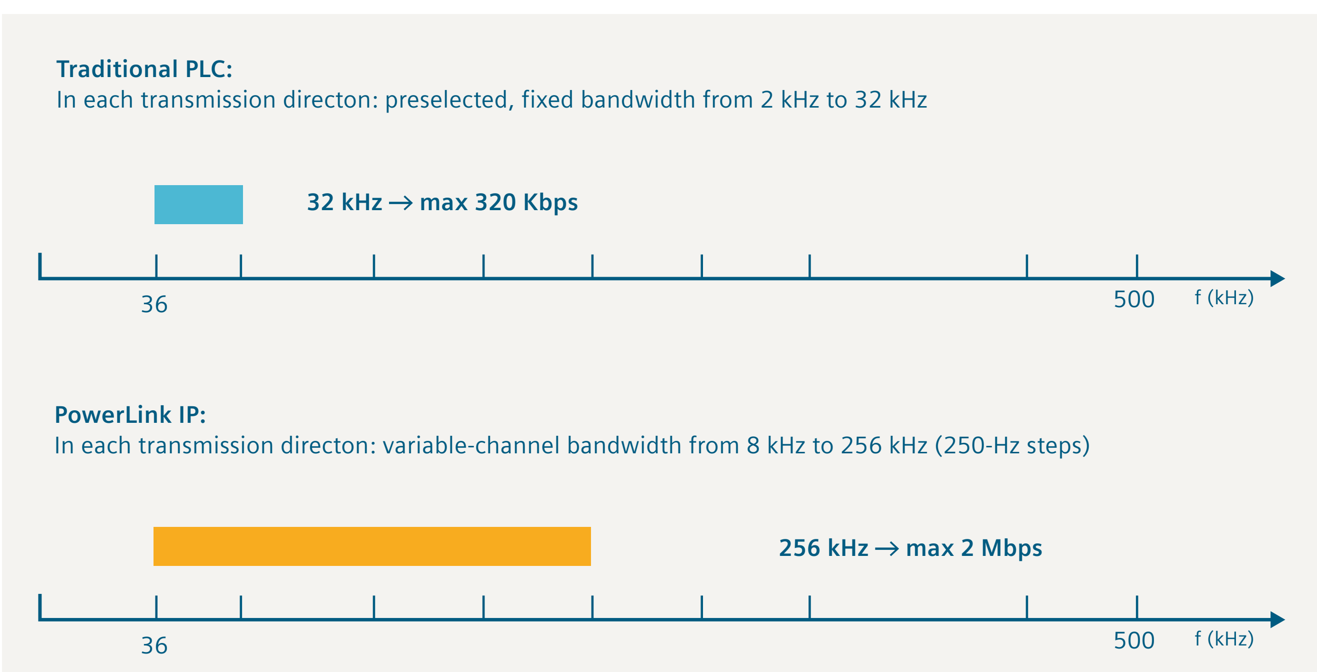


Figure 4: PowerLink IP: expanded frequency band

Efficient bandwidth utilization

In addition to the expanded frequency band, the completely new, highly efficient bandwidth utilization is a core functionality of the PowerLink IP system. Figure 5 shows the main features – notching, channel spreading, and asymmetrical data streams – in detail.

Notched frequencies

Parts of the frequency band of the PowerLink IP system's channel band can be blocked (notched) for example, if they are used by radio services. This feature enables higher data rates, because the PowerLink IP frequency band can be extended beyond the blocked frequencies.

Channel spreading

If a part of the PowerLink IP frequency band is disturbed, additional frequency bandwidth can be requested from adjacent PowerLink IP systems. Systems that are operating in adjacent channels automatically exchange information about the individual bit rate to be transmitted. The bandwidth that may be utilized by an individual system is adjusted and optimized for all systems operating in the neighboring frequency bands.

PowerLink IP adapts the data rate as a function of changes in the noise ratio on the line: for example, changes caused by external disturbances or poor weather conditions.

Figure 5 shows an initial bandwidth allocation for two PowerLink IP systems operating in adjacent frequency bands. If system 1 cannot transfer its target bit rate, it will request bandwidth that is currently being utilized by system 2. After an automated negotiation process, system 1 spreads out and extends the utilized frequency band, while at the same time system 2 reduces its bandwidth utilization.

This feature ensures maximum data throughput for all PowerLink IP systems in the event of external disturbances.

Asymmetrical data streams

The data flow from digital substations is often asymmetrical (upstream > downstream). PowerLink IP's data upstream and downstream channels can be adjusted to these different bandwidths.

This option allows the data throughput to be adapted to the special requirements of modern grid applications.

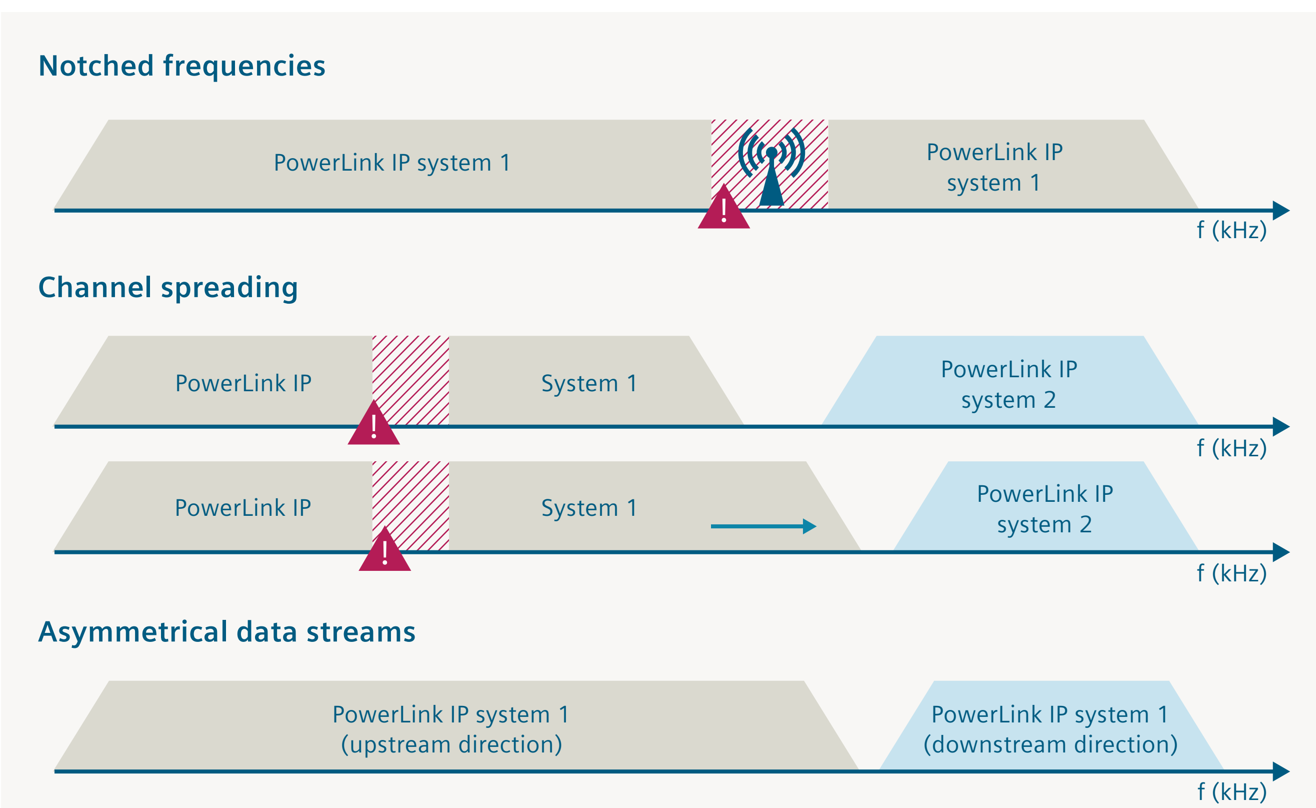


Figure 5: Efficient bandwidth utilization

Configuration example

Figure 6 shows a single communication link where the frequency band is almost fully utilized. In most cases, the entire channel bandwidth of up to 500 kHz is not available for PowerLink IP communication. Parts of the frequency band cannot be used for PowerLink IP in order to protect radio services or traditional PLC systems operating in parallel. PowerLink IP permits the utilization of a broad frequency band that is subdivided into several sub-bands. Unavailable frequencies are notched.

This configuration example shows a pair of PowerLink IP and traditional PLC systems that are sharing the communication channel of one energy line. The configuration accounts for two critical radio frequencies.

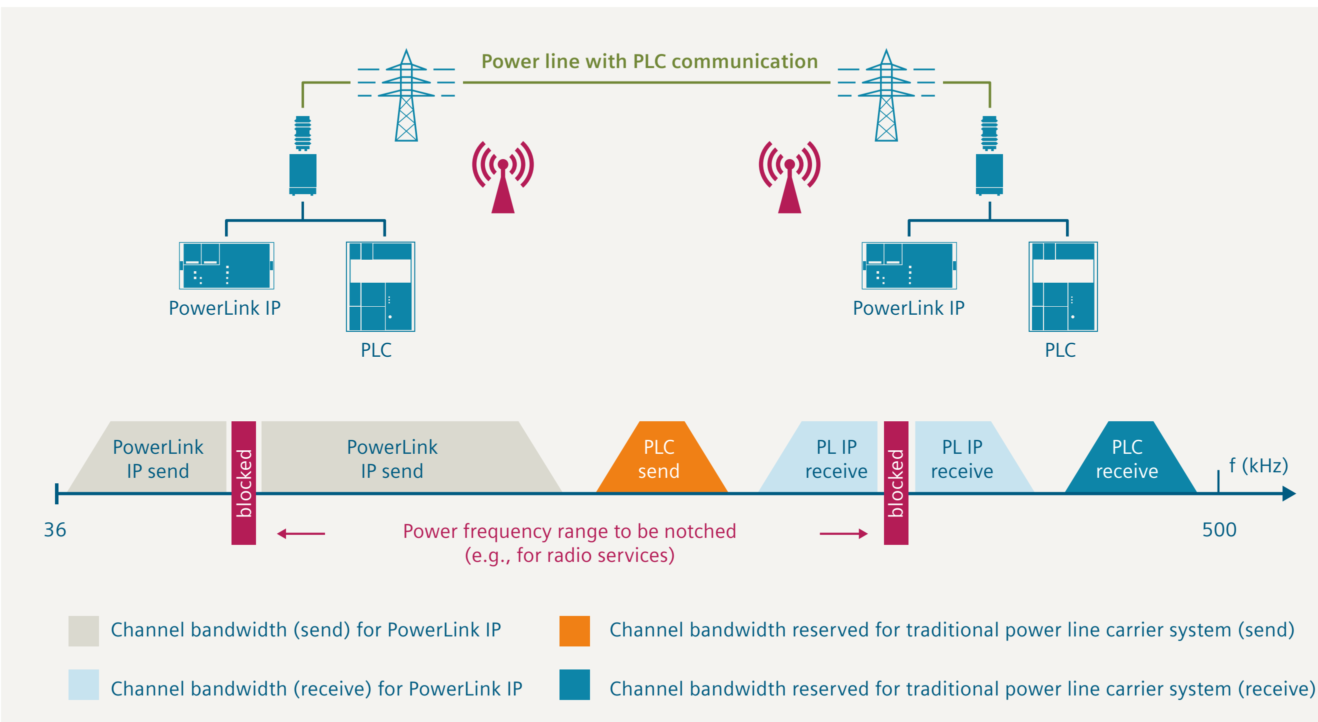
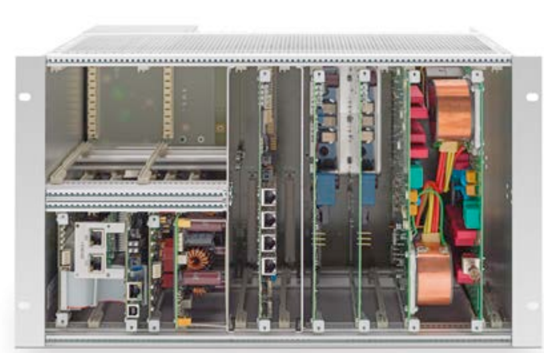


Figure 6: Configuration example (full band utilization on a single link)

Integrated teleprotection system SWT 3000

One SWT 3000 system can be integrated into PowerLink IP (see Figure 3). This SWT 3000 system can transmit up to four protection commands. The command interface type for distance protection devices can be either standard binary I/O or compliant with IEC 61850 (GOOSE). A combination of both command interface types is also supported.



PowerLink IP – typical applications

Two main application scenarios for PLC systems have been established in the field for many years.

The economical communication solution

Although the main transmission lines are usually equipped with fiber-optic cables, there are many HV substations where the installation of fiber is not cost-effective. In this case, PowerLink IP serves as an economical solution that can also provide the required bandwidth to replace alternative connections like wireless communication.

Figure 7 shows PowerLink IP as a single communication solution.

The power line is used as the sole communication path between HV substations.

PowerLink IP is connected to the power line by the traditional coupling capacitor and coupling unit. A line trap functions as a band-pass filter and separates the frequencies of the HV line segments.

PowerLink IP serves as a single communication system for the diverse communication requirements of modern, future-proof digital HV substations (IP/Ethernet).

The integrated SWT 3000 system provides the communication links for distance protection devices.

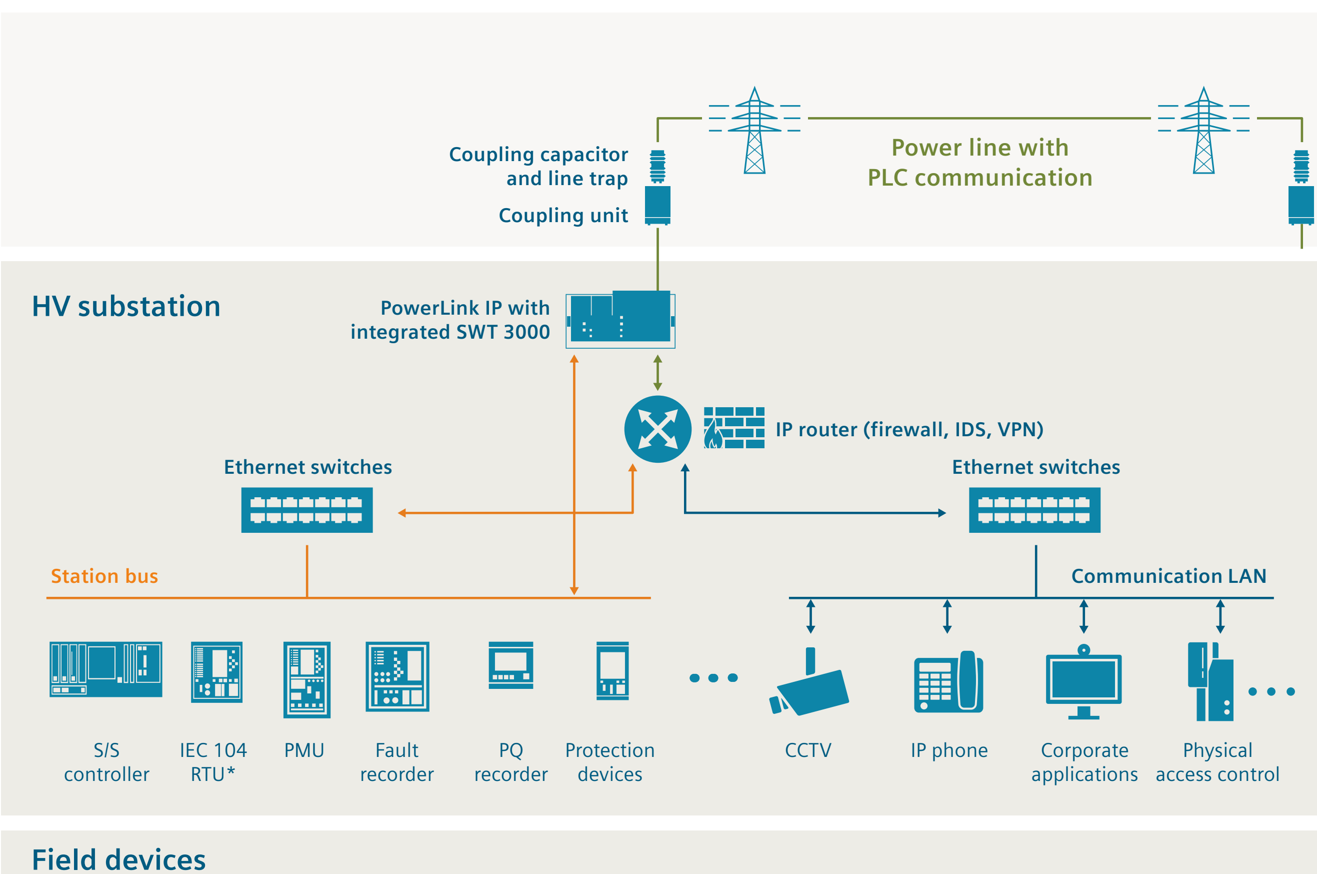


Figure 7: PowerLink IP as a single communication solution

* IEC 60870-5-104

The backup communication solution

PowerLink IP is the best solution for ensuring the highest availability of major HV links by establishing an alternative communication pathway for critical grid applications (for example, protection devices, RTUs, and voice). PowerLink IP meets the most stringent standards of transmission reliability.

Even in worst-case scenarios (for example, fiber-optic and power line interruptions), teleprotection commands can still be transmitted.

Figure 8 shows PowerLink IP as a backup communication solution in parallel with an installed fiber-optic link.

In this solution, the primary communication path is provided by Ethernet over SDH (synchronous digital hierarchy) or MPLS (multi-protocol label switching) systems. This successful combination of fiber-optic communication technology with PowerLink IP guarantees the greatest transmission reliability for critical HV links.

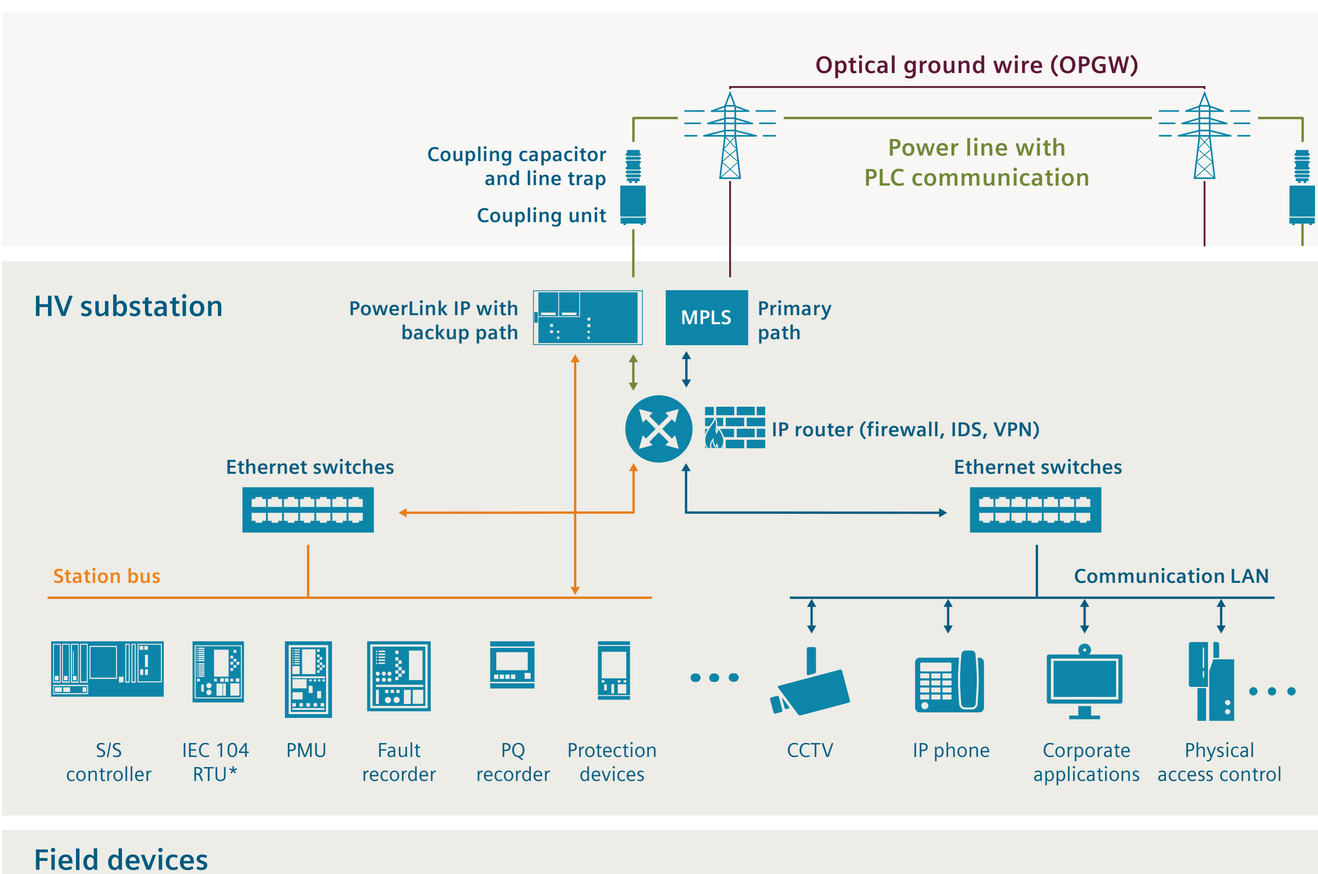


Figure 8: PowerLink IP as a backup communication solution

* IEC 60870-5-104

PowerLink IP – from traditional to digital substations

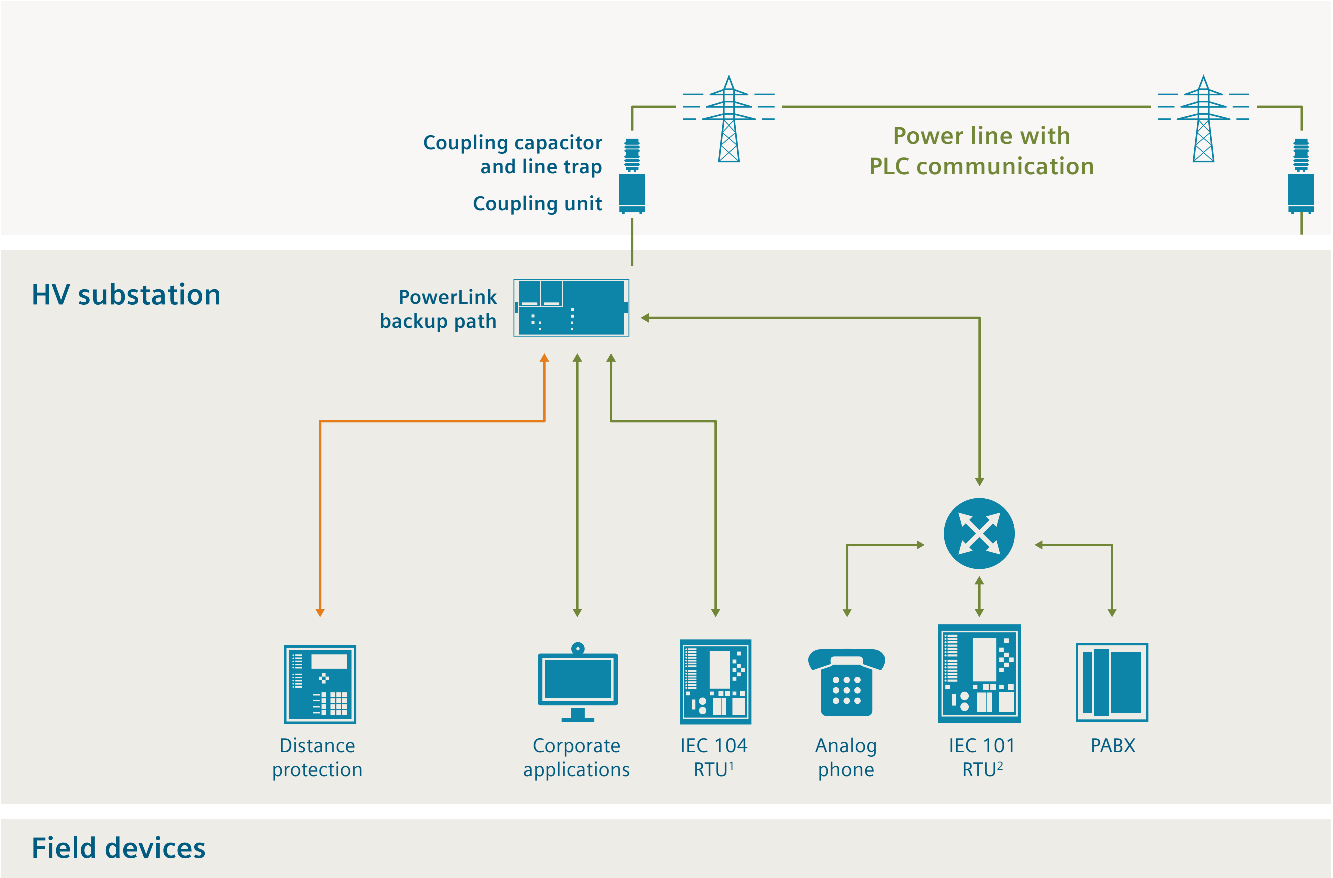
Integrating legacy devices via gateway/router

If PowerLink IP is the only PLC system in the substation, legacy devices like analog phone and IEC 60870-5-101 RTU are connected using a small gateway/router device that converts interfaces like analog voice, V.24, X.21, and E1 into Ethernet/IP protocol.

All new substation devices that have IP/Ethernet interfaces may be connected directly to PowerLink IP.

This process allows a stepwise exchange of the existing legacy devices.

Figure 9 illustrates a typical configuration.



[1] IEC 60870-5-104
[2] IEC 60870-5-101

Figure 9: PowerLink IP – connecting legacy devices via gateway/router

In many cases, transmission utilities don't intend to replace all of their legacy devices in a HV substation at once with state-of-the-art Ethernet-based equipment. Instead, they prefer a smooth step-by-step migration of the relevant devices. PowerLink IP offers two options that support this preferred process.

Coexistence of traditional power line carriers and PowerLink IP

Traditional PLC systems can also be used in parallel with a new PowerLink IP system on the same power line. In most cases, the new PowerLink IP system can be connected to the existing coupling capacitor, line trap, and coupling unit.

The traditional narrow-band PLC provides the communication link for the remaining legacy devices, and the new IP/Ethernet-based devices will be connected to PowerLink IP. PowerLink IP and the existing traditional PLC systems will utilize different frequency bands, which allows for the undisturbed operation of all the devices operating on the HV line at the same time. This solution facilitates the step-by-step replacement of legacy devices.

Figure 10 illustrates a typical solution with a subdivided frequency band.

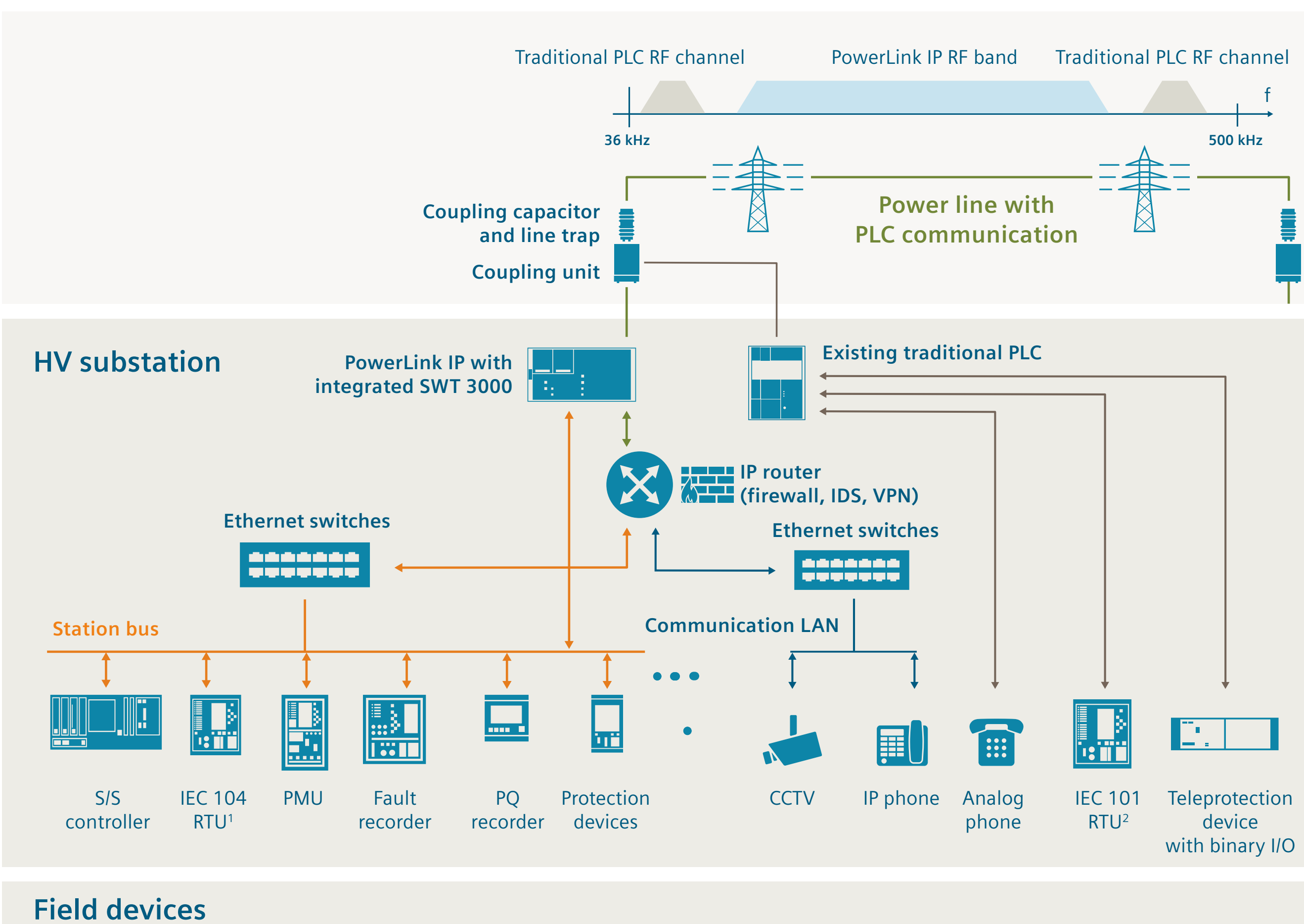


Figure 10: PowerLink IP – coexistence with traditional PLC

PowerLink IP – installation, maintanance, and management system

Installation and maintenance

PowerLink IP as a pure packet-based communication solution reduces the skills required for installation and maintenance on the communication-protocol side to Ethernet/IP.

Re-adjustment of transmit/receive frequency bands is simplified:

- fast adjustment of the Tx filter (transmit)
- no need to adjust the Rx filter (receive)

The optional integrated Spectrum analyzer delivers a fast and easy diagnosis of signals transmitted/received as well as disturbances caused by external sources. It also simplifies the re-adjustment of the transmit filter.

Frequency planning

PowerLink IP's smart, unique, and enhanced smart frequency management system provides more than just significantly extended bandwidth allocation per system node. It reduces frequency planning effort, which is limited to defining the transmit/receive center frequencies, the frequency to be notched, and the device's quality-of-service requests.

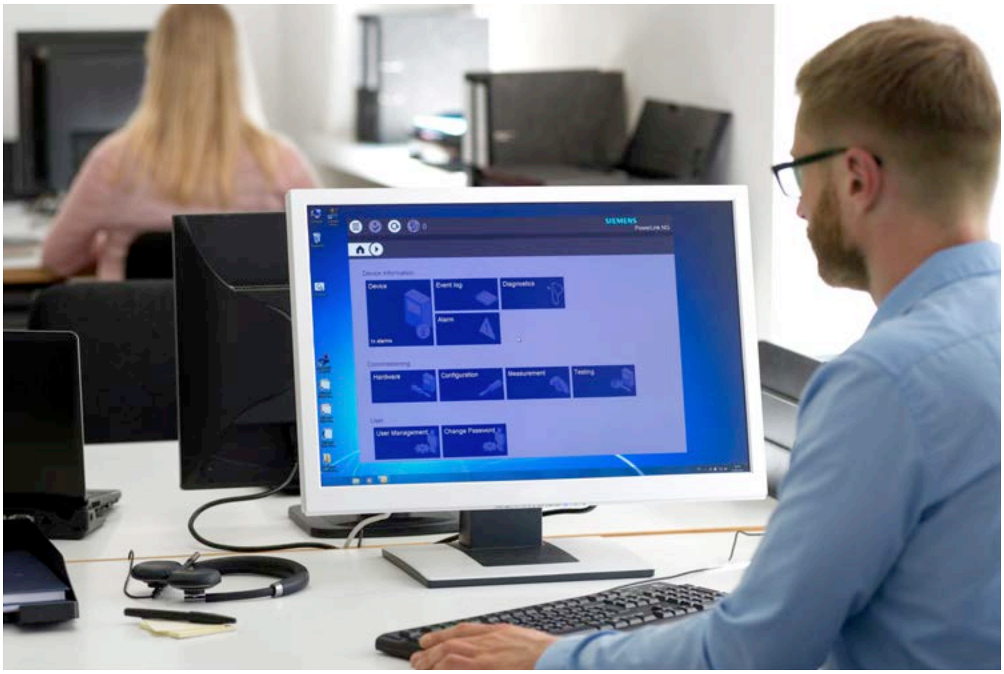


Figure 11: PowerLink IP – state-of-the-art user interface

Web-based administration

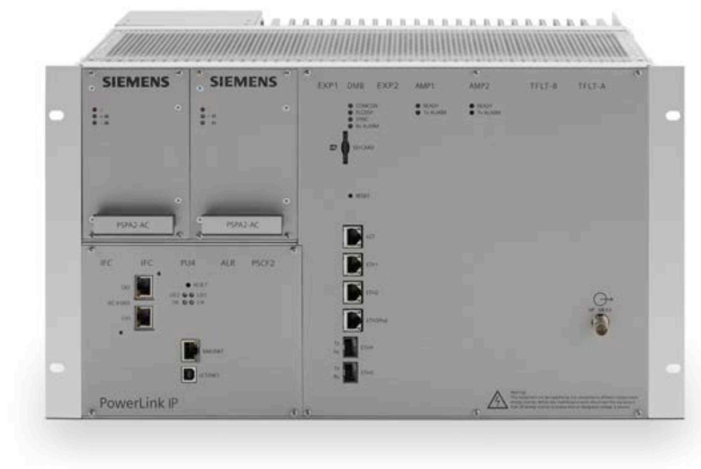
Intuitive and easy to operate, PowerLink IP uses commercial Web browsers for its system administration, which means that no additional software installation for administration or operation is required. The administration of a remote PowerLink IP system can be easily performed from the local operator console or via the corporate LAN network.

State-of-the-art encryption technology for IP packet-based transmission is complemented by access restrictions on the device's Web-based administration portal, which requires the standard user log-in and password safeguards for Power Link IP communication applications. This user interface is ready for the touchscreen operation that is already available on modern equipment like tablet PCs; see Figure 11.

Integration in network management systems

PowerLink systems can be integrated into higher-level management systems using the SNMP protocol (simple network management protocol). System and network status data can be transferred, for example, to an alarm, inventory, or performance management system.

PowerLink IP – overview of technical data and features



Technical data

Transmission method	
Modulation	Multicarrier modulation (windowed OFDM) for data; frequency shift keying for teleprotection
HF frequency range	36 kHz to 500 kHz
HF bandwidth	8 kHz to 256 kHz, 250-Hz steps
Frequency management	• Dynamic bandwidth adaptation within the frequency domain of adjacent PowerLink IP devices • Predefined bandwidth allocation • Notching of occupied frequencies (up to 20 notches) • Adjustable asymmetric traffic • Adjacent and nonadjacent Tx/Rx band operation • Teleprotection communication via MARC frequencies

HF interface	
Output power	50-W amplifier, up to +47 dBm PEP Adjustable 10 W to 50 W 100-W amplifier, up to +50 dBm PEP Adjustable 20 W to 100 W
Rated output impedance	75 Ohm unbalanced or 150 Ohm balanced
Spurious emission, return loss, tapping loss, balance to ground, receiver sensitivity, and selectivity	In accordance with IEC 60495
Tx/Rx filter	Filter bandwidth 32 kHz/min., 8-kHz steps Tx: simple adjustment using jumpers/Rx: no adjustment necessary

Transmission characteristics	
Transmission characteristics	Transmission capacity up to 2 Mbps Spectral efficiency 0.8 to 10.4 bps/Hz Minimum SNR: 42.6 dB for 16,384 QAM 36.6 dB for 4,096 QAM 30.6 dB for 1,024 QAM 24.5 dB for 256 QAM 18.2 dB for 64 QAM 11.4 dB for 16 QAM 3.3 dB for 4 QAM All values rated to 64-kHz bandwidth and block error rate (BLER) of 10E-6 (corresponding to a bit error rate (BER) of better than 10E-8)
Dynamic transmission path adaption	Modulation steps 4/16/64/256/1,024/4,096/16,384-QAM
Latency	Typically 20 ms Depending on frame length and the currently used transmission system

Ethernet interface	
Ethernet	3 x Ethernet 10/100 base TX; 1 x PoE; RJ45 2 x Ethernet 100 base FX; SFP PoE according IEEE 802.3af-2003, class 3, max. 15 W (on request only) ETH port isolation according to 802.1Q
Layer 2 switch	VLAN, IEEE 802.1Q QoS, IEEE 802.1p Full duplex, half duplex, auto negotiation

Integrated teleprotection system SWT 3000

Overview	
Number of systems	1, integrated in the PowerLink frame
Operation modes	Alternate multi-purpose (AMP)
Number of trip commands **Number of interface modules** **Number of IEC 61850 modules**	Up to 4 Up to 2 1
Modulation	Coded tripping
AMP frequencies	Trip 0.3 kHz to 2.03 kHz Guard 2.61 kHz

IEC 61850 command input/output EN100	
Electrical interface	RJ45; 100 base TX; max. range 20 m
Optical interface	SFP; 100 base TX; 1,300 nm; LC connector; max. range 1.5 km

Binary command input/output		
Input IFC-P/IFC-D		
Rated input voltage	DC 24 V to DC 250 V (tolerance: -20% to +20%)	
Nominal input voltage **24 V** **48 V or 60 V** **110 V** **250 V**	Selectable threshold voltage Low-level U_{in} < 15 V, high-level U_{in} > 18 V Low-level U_{in} < 40 V, high-level U_{in} > 47 V Low-level U_{in} < 72 V, high-level U_{in} > 85 V Low-level U_{in} < 167 V, high-level U_{in} > 198 V	
Polarity independence	Yes	
Pulse suppression	1 ms Up to 100 ms programmable in steps of 1 ms	
Command output		
	IFC-P normal contact load	IFC-D high-contact load IFC-S for signalling
Contact type	Relay, normally open contact	Relay, IFC-D normally open contact, Relay, IFC-S changeover with common root
Switching power	250 W/250 VA	150 W/1,250 VA
Switching voltage	AC/DC 250 V	AC/DC 250 V
Switching current	AC/DC 1.5 A (5 A < 2.5 ms)	AC/DC 5 A (30 A ≤ 0.5 ms)
Carry current	AC/DC 1.5 A	AC/DC 5 A for IFC-D AC/DC 1 A for IFC-S
Insulation withstand voltage	2,500 VAC	2,500 VAC

Command transmission

Transmission time T0 (SWT 3000 integrated into PowerLink)*	
Alternate multipurpose	≤ 19 ms
* Values are given for the IFC-P module and permissive tripping. For direct tripping systems, the transmission time increases by about 5 ms. If the IFC-D module is used for increased contact load, all specified transmission times are prolonged by about ≤ 4 ms.	

Security (analog transmission path)	
Probability of unwanted commands	$P_{UC} < 10^{-6}$

Dependability (analog transmission path)	
Probability of missing commands	$P_{MC} < 10^{-4}$ at SNR of +6 dB

Miscellaneous

Maintenance interfaces	
Service PC	WEB UI via Web browser, https secure protocol DHCP client for ETH interface
Service phone	Via IP telephone or PC app

Network management	
Element Manager	Web browser for local and remote access with user account/password for configuration and maintenance
Integration with NMS at higher level	Via SNMP v2/3, alarm management (up to 4 destinations for alarm traps), inventory and performance management

Event recorder	
Recording capacity	PowerLink IP: 10,000 events and iSWT: 8,000 events
Real-time clock	NTP, IRIG-B, line clock sync, 1 ms resolution

Alarm module input/output

Binary input 1 of ALR module for synchronization with:	
Sync pulse **Nominal voltage** **Polarity independence**	 DC 24 V to DC 250 V (tolerance: -20% to +15%) Yes
IRIG-B **Nominal voltage** **Polarity independence**	 DC 5 V, DC 12 V, DC 24 V (tolerance: ±15%) No, defined polarity required

Output ALR Module (relay)	
Number of alarm outputs	3 relay contacts
Contact type	Changeover contact
Switching power	300 W (DC), 1,000 VA
Switching voltage	250 V (DC or peak AC)
Switching current	5 A (DC or peak AC)
Carry current	1 A (DC or peak AC)

Power supply

Input voltage range	
PSPA2-DC	DC 38 V to DC 72 V
PSPA2-AC	AC 93 V to AC 264 V (47 Hz to 63 Hz) and DC 85 V to DC 264 V
Power consumption	
50-W Amplifier (AC/DC)	Typical value at normal operation 301 VA/104 W Typical value at max. operation 394 VA/146 W
100-W Amplifier (AC/DC)	Typical value at normal operation 358 VA/131 W Typical value at max. operation 559 VA/215 W

EMC immunity

Immunity in industrial environments – generic standard IEC 61000-6-2, for test levels see table. Immunity for equipment used in power station and substation environments IEC 61000-6-5, for test levels see table in ().

Standards	Test levels
Electrostatic discharge **IEC 61000-4-2**	Direct/indirect contact discharge: 4 kV (6 kV) Air discharge: 8 kV
Radiated, immunity **IEC 61000-4-3**	80 MHz to 1,000 MHz 10 V/m; 1 GHz to 6 GHz 10 V/m
Electrical fast transient **IEC 61000-4-4**	AC/DC supply lines: +/-2 kV HF input/output lines: +/-1 kV (+/-4 kV) Data input/output: +/-1 kV (+/-2 kV)
Surge immunity **IEC 61000-4-5**	1.2/50 us (8/20) pulse Signal/control lines: +/-1 kV line to ground (+/-1 kV line to ground) HF input/output lines: +/-1 kV line to ground (+/-2 kV line to ground) DC supply lines: +/-0.5 kV line to ground; +/-0.5 kV line to line (+/-2 kV line to ground; +/-1 kV line to line) AC supply lines: +/-2 kV line to ground; +/-1 kV line to line
Immunity to conducted disturbances **IEC 61000-4-6**	0.15 MHz to 80 MHz 10 Vrms (signal lines > 3 m and AC/DC power supply lines)
Power frequency magnetic field immunity **IEC 61000-4-8**	50/60 Hz; 30 A/m (100 A/m; 1,000 A/m for 1 s)
Voltage dips AC supply line **IEC 61000-4-11**	70% U for 1 period 40% U for 50 periods
Voltage interruptions AC supply line **IEC 61000-4-11**	0% U for 5 periods and 50 periods

Standards	Test levels
Test for immunity to conducted common mode disturbances IEC 61000-4-16	(Signal/control lines: 50/60 Hz; 10 V and 100 V for 1 s (HF input/output lines: 50/60 Hz; 30 V and 300 V for 1 s) (DC supply lines: 50/60 Hz; 10 V and 100 V for 1 s)
Ripple on DC input power port immunity IEC 61000-4-17	(DC supply lines: 10% Un)
Damped oscillatory wave immunity test IEC 61000-4-18	(HF input/output lines: 1 MHz; 2.5-kV common mode and 1-kV differential mode)
Voltage dips, short interruptions, and voltage variations on DC input power IEC 61000-4-29	70% U for 0.1 s 40% U for 0.1 s 0% U for 0.05 s

EMC emission

Standards	Test levels
Emission standard for industrial environments	Class A

Safety

Audio/video, information and communication technology equipment: safety requirements IEC 62368-1

International standards

Single side-band power line carrier terminals	IEC 60495 *) IEC 62488-2 ED1 *)
Climatic conditions	IEC 60870-2-2

* Valid for applicable parameters on digital PLC

Climatic conditions

Standards	Test levels
Cold **IEC 60068-2-1**	-10 °C
Dry heat **IEC 60068-2-2**	+55 °C
Damp heat, cyclic **IEC 60068-2-30**	+25 °C at 95% humidity +55 °C at 93% humidity
Change in temperature **IEC 60068-2-14: method Nb**	-10 °C to +55 °C

Mechanical conditions

Standards	Test levels
Degree of protection	IP 20
Vibration stationary use **IEC 60068-2-6**	Resonance: 5 Hz to 9 Hz: 0.35 mm amplitude 9 Hz to 500 Hz: 1 m/s² acceleration
	Endurance: 5 Hz to 9 Hz: 3.5 mm amplitude 9 Hz to 200 Hz: 10 m/s² acceleration 200 Hz to 500 Hz: 15 m/s² acceleration
Test of dynamic behavior during mechanical stress (shock test) **IEC 60068-2-27: test Ea**	Half sine; 30 g acceleration; duration 18 ms

Mechanical design

19” frame	
Dimensions	482 mm x 266 mm x 300 mm (W x H x D)
Weight	17 kg 50 W; 19 kg 100 W

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