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Power line carrier communication

for digital transmission grids

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A revolution in Power Line Communication technology

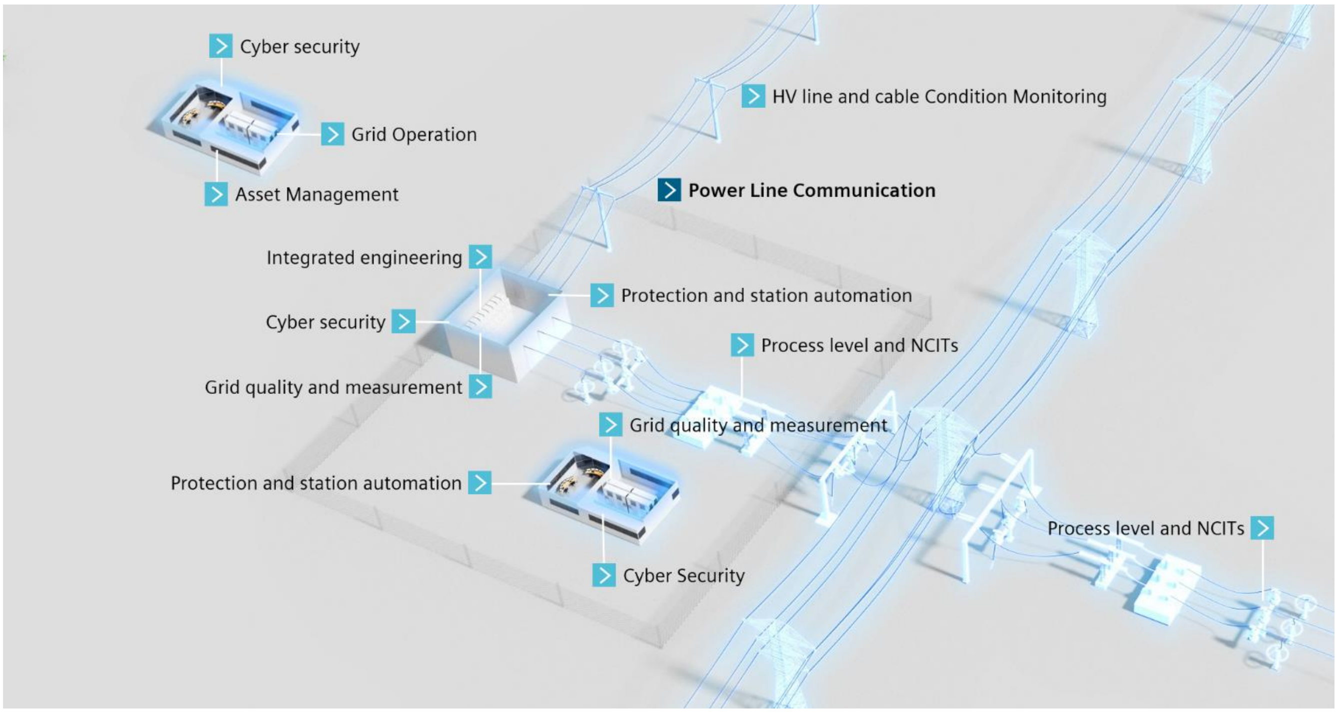
The concept of using high-voltage power lines for communication has a 90-year old history. Its purpose was and still is to keep mission-critical communication in the hands of the power utility. During that time, this technology underwent major changes. Initially designed for teleprotection signaling using analog technology, its scope meanwhile includes voice and even digital data. Since ~2005, however, digital power line communication (PLC) stagnates. Systems are typically used as stand-alone equipment, not integrated into any IT infrastructure, with rather rigid frequency constraints supporting a maximum data rate of up to 320 kbps.

In 2018, Siemens revolutionized the PLC market by releasing a solution that tore down the rigid frequency boundaries. This state-of-the-art device is fully integrable into IT infrastructure and allows data rates up to 2 Mbps, opening new fields of application and thus brings communication back into the command of power utilities.

Challenging Market Environment

1. Energy market in transformation

The ecosystem of energy generation, transmission, and distribution is going through a period of radical change. All involved players face new challenges driven by social and political forces. The growing trend from centralized to decentralized power generation make the reliable and cost-efficient management of complex transmission and distribution networks a necessity. The rapid growth of network digitalization further adds to this complexity and leads to an increasing demand for data communication. It is, however, not obvious that every substation or network node has access to a high-speed communication link or a reliable cellular connection.

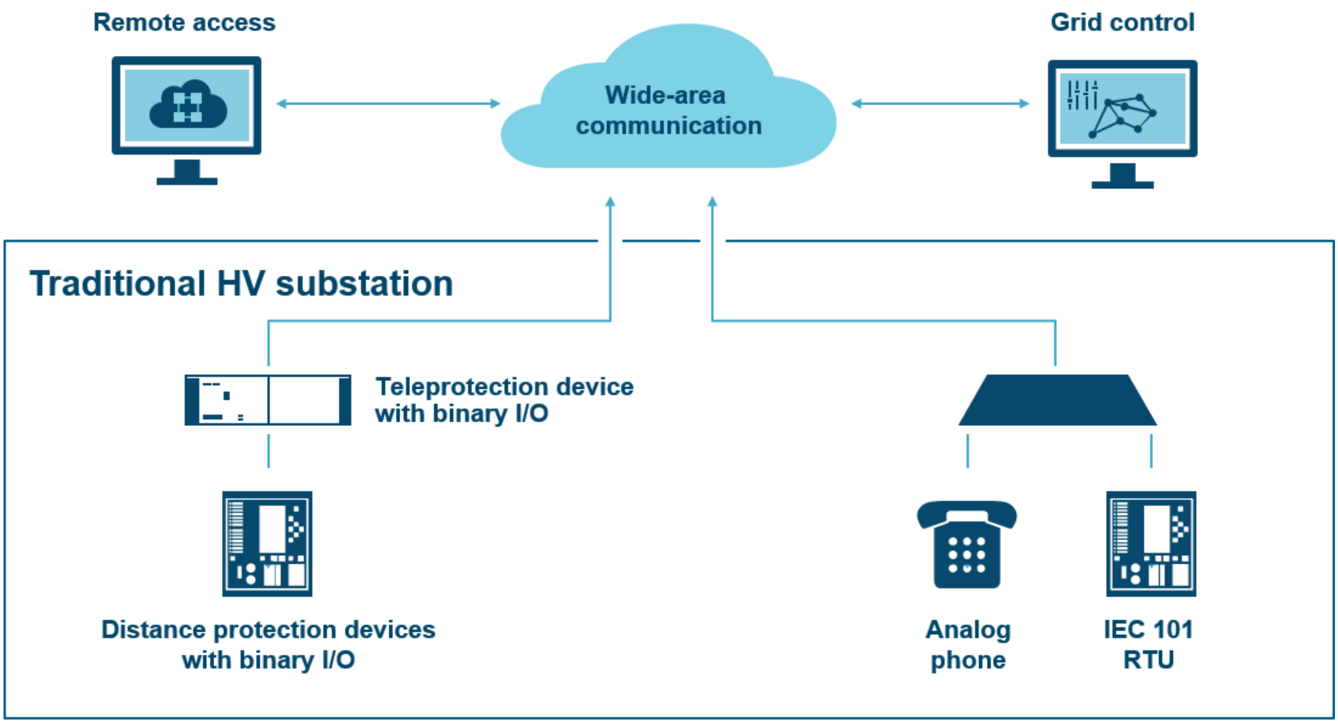


Elements of digital substations

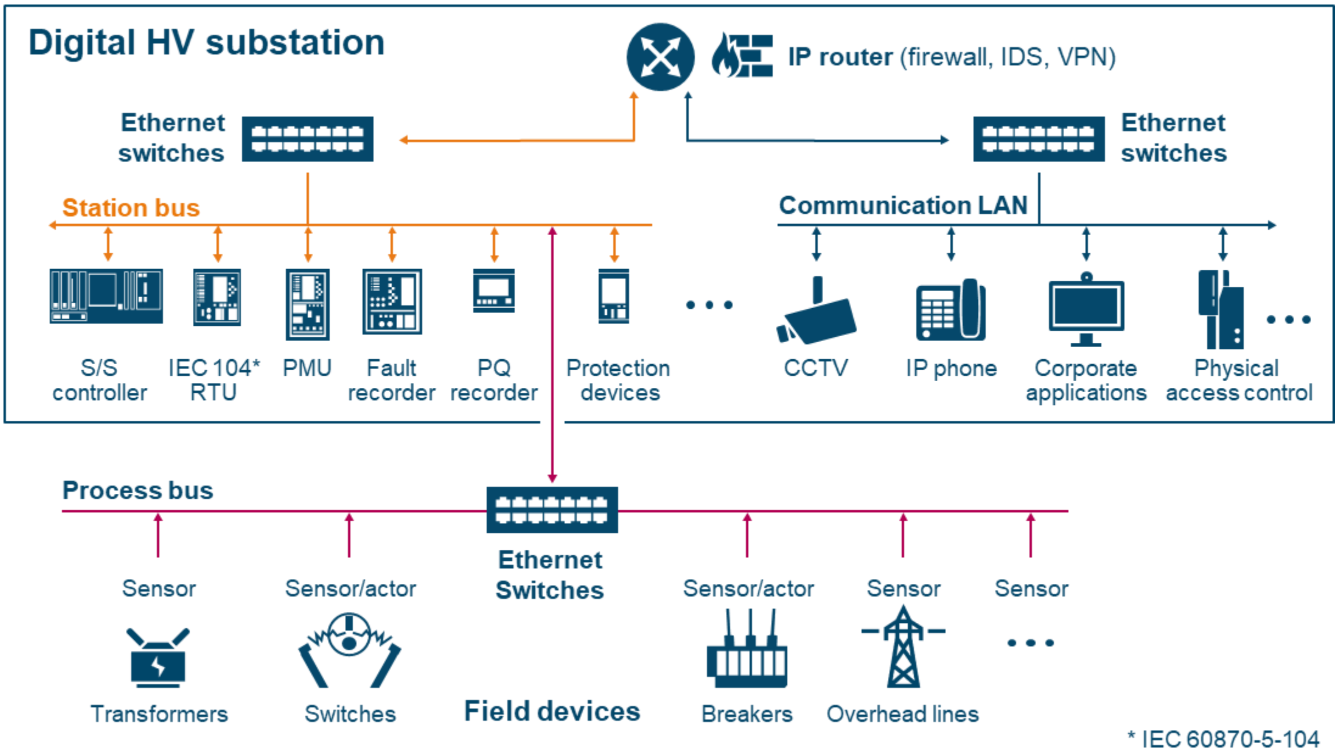
2. From conventional to digital substations

A substation is a system consisting of primary technology (including switchgear and transformers), secondary technology (grid protection, automation, telecontrol systems, and more) and associated infrastructure, such as communication between substations or between substation and control center. Typical communication requirements in traditional high-voltage (HV) substations range from binary teleprotection signals, control center commands, up to analog voice. All these applications require only low to very low bit rates. The corresponding communication needs can easily be covered by classical power line communication solutions. Further, such devices are typically not integrated into any enterprise IT infrastructure.

New digital HV substations use packet-based communication infrastructure and require broadband data traffic. In addition to the communication requirements of legacy stations, big data and central data analytics, supervision or even access control lead to significantly higher bandwidth requirements. Substation digitalization is an ongoing process that can be accelerated and facilitated by a smooth migration of the communication infrastructure.



Features of a traditional HV substation



Features of a digital HV substation

3. Future of power line communication

Even though the rollout of modern digital substations will most certainly include fiber-optic cable, a comprehensive country-wide coverage by fiber-optic infrastructure is still far away in many regions of the world.

First, remote substations require extensive investment to bring fiber-optic cable to the substation. Even in central urban areas, putting fiber to the substation may not be economically viable. Second, refurbishing existing transmission lines with optical ground wire may not even be possible due to the static design of the prevailing pylons. In any case, such an expansion not only requires massive construction; it for sure is very cost intensive. Third, a modernization will take quite some time during which it is economically important to simultaneously serve legacy and future infrastructure with technology capable of migrating between both worlds. And finally, a reliable backup solution may still be needed to ensure a minimum communication link in case of fiber break or malfunction.

A new way of power line communication capable of high data rate but still being compatible with legacy infrastructure and classical devices can be such a solution.

Benefits of Siemens solution

4. The new world of power line communication

HV power line carrier systems typically operate in the frequency range up to 500 kHz, use a bandwidth of up to 32 kHz per system, and support maximum data rates of up to 320 kbps. This is by far insufficient for modern digital substations.

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 high and reliable bandwidth. These applications need IP and Ethernet as their main broadband communication infrastructure inside (LAN) and outside (WAN) the substation. In contrast to classical, symmetrical communication, the data flow in the digital world is predominantly asymmetrical. Few control commands flow downstream from the control center to the substation, while big data or bandwidth-consuming applications demand a broad upstream channel. Integration into the utility's enterprise IT infrastructure is standard procedure for efficient transmission network management. Support of state-of-the-art cyber security measures is an obligatory feature.

5. A revolution in PLC technology for digital transmission grids

HV link up to 500kV

- Data communication
- Teleprotection signaling

Benefits

- Re-use of existing infrastructure
- Independent of external communication service provider
- Own control of communication infrastructure
- IEC60834 standard-based reliable communication

Extended data rate

- Up to 2Mbps per direction

Benefits

- Data rate ~10× legacy devices
- Transmission of video, voice, data
- Consolidation of traditional devices

Smart frequency management

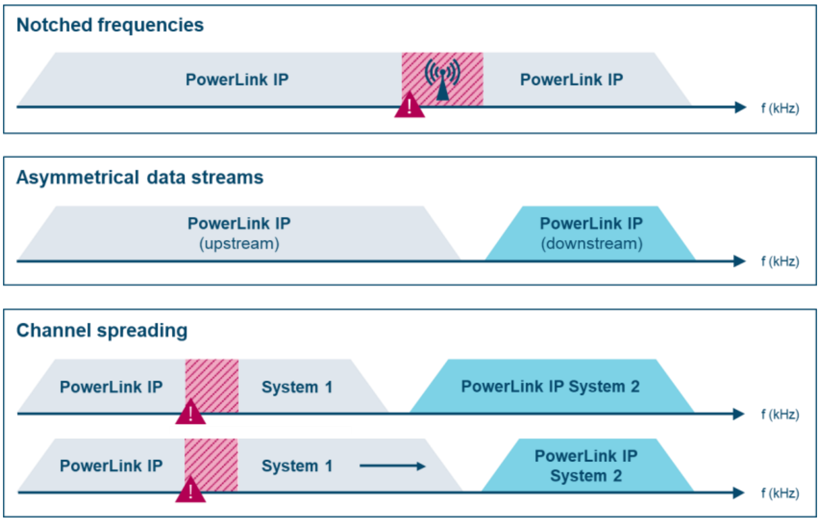
- Flexible bandwidth allocation up to 256kHz
- Frequency notching

Benefits

- Maximum usage of frequency band as most valuable and scarce resource
- Use of non-contiguous frequency bands
- Simplified frequency handling

- Channel spreading
- Asymmetrical traffic pattern

- Dynamic adaptation depending on line condition
- Easy integration into existing PLC infrastructure
- Ideally suited for specific communication requirements of modern grid applications



High availability

- Synchronization time < 1 sec
- Automatic levelling

Benefits

- Maximum throughput with minimum frequency usage
- Restoration of communication link failures
- Robust system even under most adverse conditions

Optimized for Ethernet-LAN/IP

- Fully packet-based technology
- Integration into IT environment

Benefits

- IP know-how readily available
- Full integration into customer-specific workflow
- Future-proof technology

6. System design

The Siemens' PowerLink IP system is based on a pure packet-based architecture with a software-defined modem. Windowed OFDM is applied to maximize the spectral efficiency of the system. The result of this approach is an achievable data rate of up to 2 Mbps and low sensitivity to external and internal disturbances such as radio sources, neighboring PLC devices or frequency side lobes.

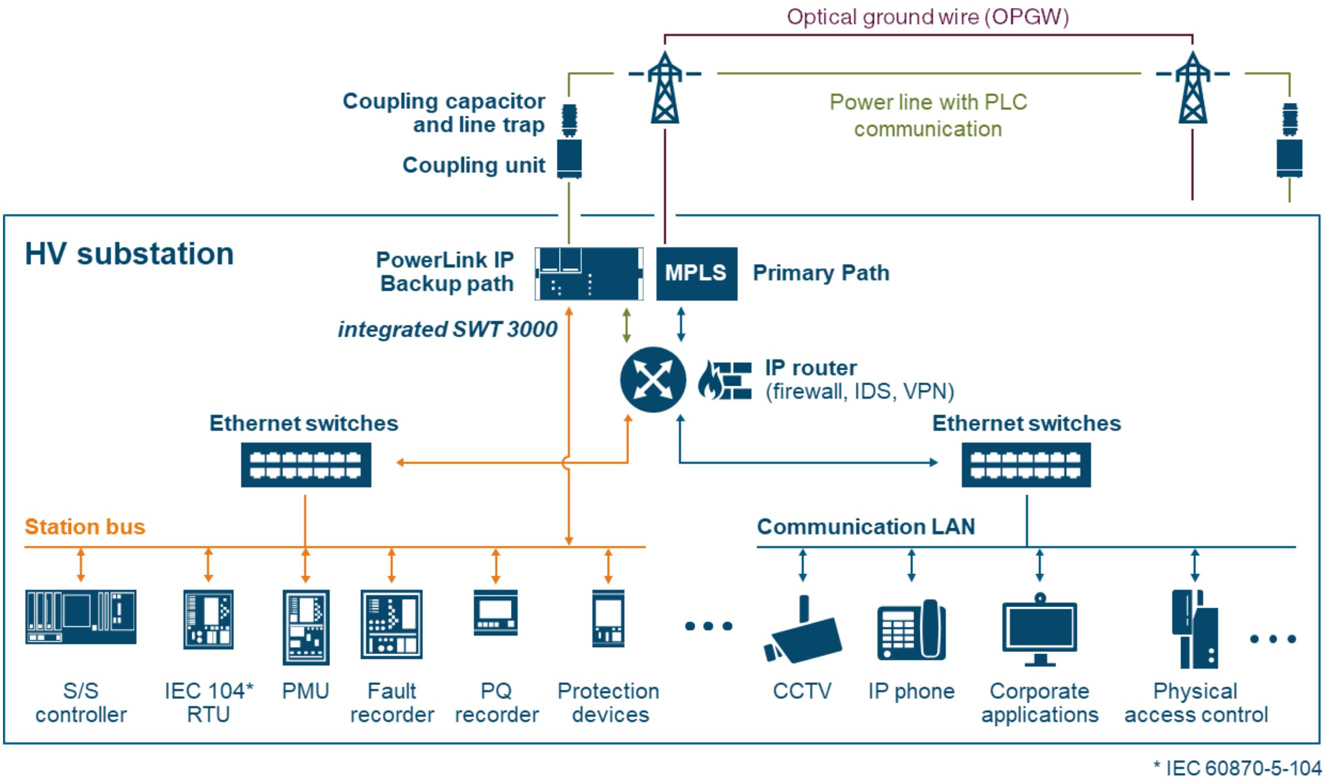
The heart of the system is the digital modulation board that contains an integrated L2 switch and provides six Ethernet interfaces. The LCT interface is intended for local administration, whereas the three electrical and two optical Ethernet interfaces are used for the connection of substation devices. 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. It is connected to a coupling unit. The integrated teleprotection system SWT 3000 transmits up to four protection commands and provides binary I/O and GOOSE (IEC 61850) interfaces.

Impact on your business

7. Most economical communication solution

Power line communication serves as an economical solution that provides the required bandwidth to replace or to complement alternative communication technologies like wireless or even fiber-optic. The power line itself may even be used as the sole communication path between your HV substations and control center. Just connect to the existing power line through a traditional coupling capacitor and coupling unit. Power line communication allows the utility to (re)gain control over its critical communication infrastructure.

8. More reliable than fiber-optic



Powerline as backup for fibre-optic communication

Power line communication is the ideal solution for ensuring highest availability of major HV links by establishing an alternative communication pathway for critical grid applications (for example, protection devices, RTUs, and voice). It 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.

If used as a backup communication solution parallel to an installed fiber-optic link, the primary communication path will be provided by Ethernet over SDH (synchronous digital hierarchy) or MPLS (multi-protocol label switching) systems. This successful combination of fiber-optic communication technology with power line communication guarantees the highest transmission reliability for your critical HV links.

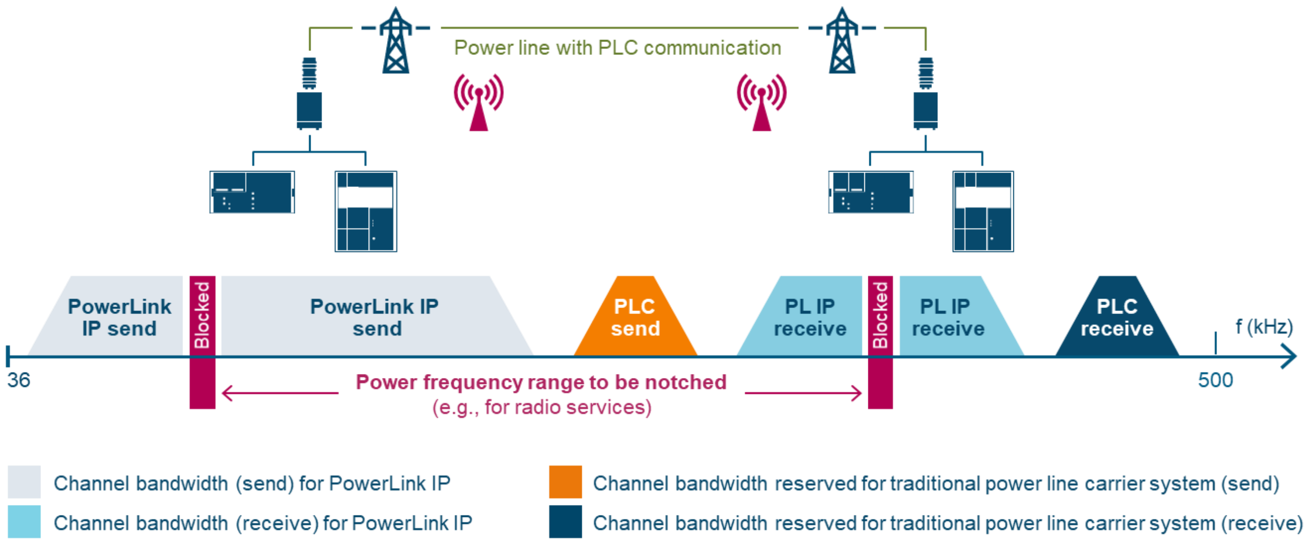
A modern packet-based power line solution reduces the skills required for installation and maintenance on the communication-protocol side to Ethernet/IP. Smart frequency management can significantly reduce the frequency planning effort that is limited to defining transmit/receive center frequencies, notch frequencies and quality-of-service requests.

9. Migrate to digital substation at your own pace

All new substation devices with IP/Ethernet interfaces may be connected directly to PowerLink IP. Legacy devices like analog phone and IEC 60870-5-101 RTU can be connected using a small gateway/router device that converts interfaces like analog voice, V.24, X.21, and E1 to Ethernet/IP protocol. This process allows a stepwise exchange of existing legacy devices.

Traditional PLC systems may be used parallel to the modern 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. If desired, the traditional narrow-band PLC can be used to provide the communication link for remaining legacy devices, while the new IP/Ethernet-based devices will be connected to the new packet-based PLC system.

Packet-based PLC and existing traditional PLC systems utilize different frequency bands, which allows for the undisturbed operation of all devices operating on the HV line at the same time. This solution offers a step-by-step replacement of legacy devices, facilitating a smooth migration from traditional to digital substations.



Use of non-contiguous frequency bands for powerline communication

Abbreviations

HV	High Voltage
IEC	International Electrotechnical Commission
IP	Internet Protocol
IT	information Technology
LAN	Local Area Network
MPLS	Multi-protocol Label Switching
OFDM	Orthogonal Frequency Division Multiplex
PLC	Power Line Communication
PMU	Phasor Measurement Unit
RTU	Remote Terminal Unit
SDH	Synchronous Digital Hierarchy
WAN	Wide Area Network

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