An investigation into the use of communication technologies for medium- and high-voltage smart power grid

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Abstract:
The good performance of a smart power grid, better known as a "Smart Grid", depends on the communication system used, hence the importance of having the appropriate technology. This article presents the communication technologies used in high and medium-voltage environments, and the main objective is to document the general characteristics of each of them, their applications, limitations, and the standards used. For the sake of comprehension, they are classified according to their type, wired and wireless.
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1. Introduction

The planet is on its way to facing an energy crisis, so measures that can be taken today should not be delayed, and one of the solutions to this problem is the implementation of a modernised electricity distribution system that allows for efficient energy management. In response to this need [1,2], Smart Grid has emerged, which provides intelligence to the electrical power system, thus enabling the efficient management of electrical systems where losses can be reduced and real consumption can be effectively identified and controlled. consumption is effectively identified and controlled.

The Smart Grid concept refers to a modernized electricity distribution system that performs automated control of the flow of energy from the generating plant to the consumers, providing greater security, cost-effectiveness, and efficiency. It is characterised by the bidirectional flow of energy and information, allowing the user to interact directly with the generating plant. generating plant. The Smart Grid also includes services such as the control of appliances, energy savings and cost reduction, providing the customer with tools to help them the customer with tools to help them decide how and when to use energy responsibly. consume energy responsibly [3,4]. Another important aspect to Another important aspect to consider with the implementation of a Smart Grid is the reduction of the environmental impact, by reducing energy waste by providing only the energy that is requested; and by incorporating energy from alternative sources such as wind and solar energy.

The advantages offered by the modern smart power grid are only possible if the right communication technology is used, as it is this that will enable power flow control, fault monitoring, and reliability of the entire system [5,6]. This is why this selection must be made very carefully, taking into account your application environment and the requirements of the network, as this will depend on the proper functioning of the entire power distribution system. The importance of a good communication system for Smart Grid is indicated in [7,8] and [9] and some of the applied technologies are explained. applied. Similarly, taking into account the importance of a good communication system, in [9], the importance of a good communication system is explained. communication system, in [9] the requirements to be met by future communication architectures are future communication architectures and proposes a model called Grid Stat (framework). a model called Grid Stat (middleware framework providing a programming interface) to meet the programming interface) to meet the future needs of the power grid. of the electricity distribution network.

The communication infrastructure is based on three types of networks: home area network, neighborhood area network, and wide area network, which is shown in Figure 1.

Figure 1. Smart grid communication infrastructure [10].

Figure 1 shows a diagram showing the parts of an electrical power network and the associated communication network. The home area network (HAN) provides access to appliances and the wide area network (WAN) connects the power generation center, the transmission center, and the control center. This article refers to the power distribution network in the WAN coverage area, providing information on the communication technologies used and the standards that govern them. The communication technology used will depend on the coverage area of the network.

The communication technologies implemented in high and medium voltage are explained below, classifying them according to their type as wired or wireless. Each of these technologies are explained taking into account their most important applications, and the limitations presented depending on their coverage area and the vulnerability to electromagnetic waves to which they are exposed. to which they are exposed.

2. Communication technologies implemented in Smart Grid

The use of the first wireless communication technologies, in the context of smart grids, is presented in [11], with the purpose of supporting the traffic needs of transmission lines. This was followed by proposals to support low-loss transmission over the network under the IEEE 802.21 standard (which provides the information that makes data transfer between two base stations possible). Subsequently, other standards continue to be implemented to enable the integration of applications, techniques and technology solutions that are available for the smart power grid but lack widely accepted standards, some of which are explained in [12].

Another important aspect to be taken into account for the selection of the appropriate communication technology in high and medium voltage environments is that the communication infrastructure in the Smart Grid is composed of three network sectors: backbone, middle mile, last mile, and last mile. (backbone), middle mile, last mile. The core corresponds to the high-voltage sector of the electricity distribution network. It supports the connection between numerous substations and distributors. It covers a wide area network (WAN) and requires high bandwidth capacity for data transfer. This network is usually fibre optic, but Ethernet, PLC (see Figure 2), satellite communication, etc. can also be used.

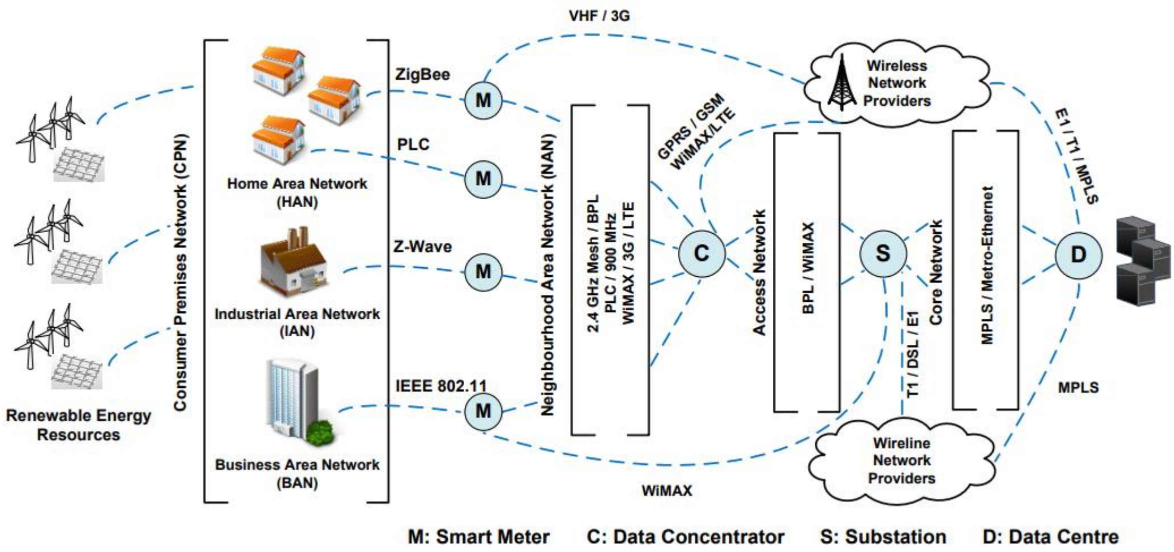

Figure 2. Communication technologies in Smart Grid [13,14].

The medium-mile sector corresponds to the medium-voltage area of the electricity distribution network. It connects the advanced metering infrastructure (AMI) with substations and distribution systems. It includes WiMAX technology, LTE, 3G, fibre optics, PLC, etc. Last mile sector, corresponds to the low voltage area and includes the network regions interconnecting the households present in an area (NAN), HAN and AMI. A variety of wired and wireless and wireless technologies can be deployed in this sector [11]. The most commonly used communication technologies in the high and medium voltage sectors are explained below. used in the high and medium voltage sectors are explained below.

3. Wireless technologies

Wireless communication technologies have been developed for the transfer of data between two or more points without the need for a physical infrastructure between them. In addition, they have several advantages, such as low implementation cost, fast deployment and mobility, which make them very attractive for use in smart power grids (see Figure 3). However, they have to face some challenges for their implementation in Smart Grids, such as resistance to electromagnetic interference [7,8].

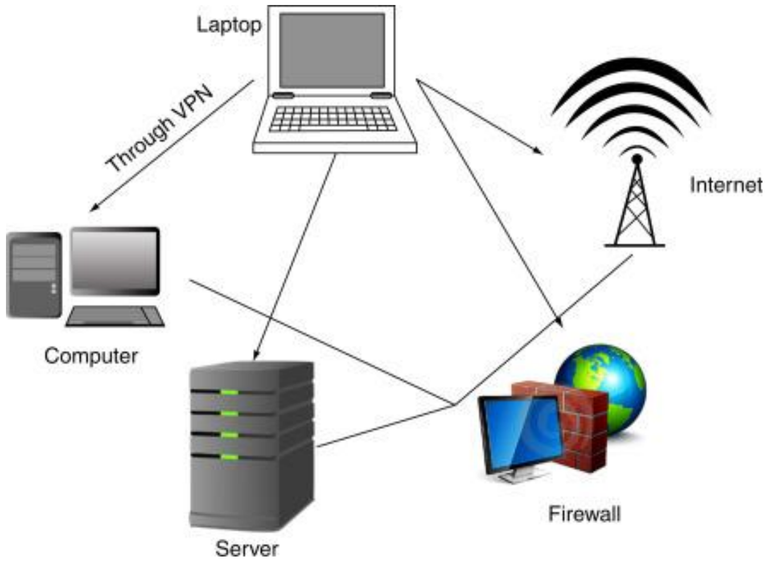

Figure 3. Wireless Technologies [15].

3.1.Wireless LAN

It provides high-speed point-to-point and point-to-multipoint communication. This technology was adopted under the IEEE 802.11 (Wi-Fi) standard, which allows multiple users to occupy the same frequency band with minimal interference between them. between them. The various versions of the 802.11 standard are: IEEE 802.11b, 802.11a, 802.11g, 802.11n and 802.11i, which feature data rates from 11 Mbps to approximately 600 Mbps, in the 2.4 GHz and 5.8 GHz frequency bands. They use DSSS and OFD modulation techniques. DSSS and OFDM modulation techniques. In addition, 802.11i known as WPA2 is used for improve the security cyber security at the networks LAN networks.

Wi-Fi enables many applications within the Smart Grid context, such as automation, protection and control of resources. Among the most prominent applications based on the IEC 61850 standard, explained in [12], are: strengthening transformer protection, redundant link for automated distribution system, power line protection, and control and monitoring of remote renewable energy sources. of remote renewable energy sources.

On the other hand, this technology has some limitations such as: poor availability of the wireless signal, it is affected by electromagnetic radiation in high voltage locations and not least, interference caused by radio frequencies that affect the operation of the equipment. radio frequencies that affect the performance of the equipment.

3.2.WiMAX

A WiMAX network provides a bandwidth of 5 MHz with a speed of up to 70 Mbps over a distance of 48 km. For fixed-band communication the 3.5 and 5.8 GHz frequency bands have been allocated, while for mobile communication the 2.3, 2.5 and 3.5 GHz bands have been allocated. Licensed spectra provide higher power and transmission distance, which makes them more suitable for long distance communication. It is governed by the IEEE 802.16d (fixed) and 802.16e (mobile data) standards. WiMAX offers a number of capabilities, in addition to its excellent latency, that make this technology a good choice for controlling Smart Grid applications. It has adaptive modulation and power control. WiMAX also allows an operator to prioritize data traffic through what is known as Quality of Service (QoS).

The applications provided by WiMAX in the context of smart grids, as outlined in [7,8], include as outlined in are:

- Wireless Machine Readable Networks (WMAR), thanks to its wide coverage and high speeds. coverage and high speeds.
- It provides real-time prices to consumers connected to the electricity distribution network thanks to its good latency [9].
- Outage detection and restoration.

The limitations of a WiMAX network implementation are WiMAX network are:

- The cost of building a WiMAX tower is relatively high, as it must be built in an optimal way to meet the quality of service. to meet the quality of service.
- Frequencies above 10 GHz cannot penetrate through obstacles. through obstacles.

3.3.Cellular technology

It is a radio network distributed over a large land area, served by a transceiver with a fixed location known as a base station. It includes 3G and 4G technology operating in the 824-894 MHz and 1900 MHz range. Cellular communication systems are fast and inexpensive and allow data communications coverage over a large geographical area. The data transfer rate is 60-240 Kbps, and the distance depends on the availability of cellular service. Data transmission is exchanged from cell to cell facilitating uninterrupted data flow. The advantage of cellular technology is that the infrastructure is already in place, so it can be used for deployment. In addition, with the recent growth of 3G and 4G cellular technology, data rates and quality of experience (QoE) have greatly improved. much improved.

The following applications of cellular technology are Smart Grid oriented: SCADA (supervisory control and data acquisition) interface for remote distribution substation due to the large coverage it offers and remote renewable energy sources monitoring and metering. A major limitation of cellular technology is that it generally takes time to establishment of communication usually takes time and data communication is not prioritized in case of and data communication is not prioritized in case of special events. events.

3.4. Satellite communication

It provides communication between multiple earth stations, allowing access to remote locations. This type of communication functions as a relay as it has the ability to receive and retransmit information via a receiver/transmitter device, called a transponder. It uses different frequencies for reception and retransmission in order to avoid interference between signals. interference between the signals.

Among the applications of this technology for Smart Grid are:

- Remote control and monitoring, as it allows for global coverage. global coverage. This is due to the fact that in some places there is no communication infrastructure due to their remote location. communication infrastructure does not exist in some places due to their remote location.
- Integration of renewable energy generators that are usually located in remote areas. are usually located in remote areas.
- Backup when terrestrial communication infrastructures are affected by natural disasters or system failures.

Satellite communication also has some limitations such as:

Satellite systems have a longer delay than other communication systems. communication systems.

The characteristics of the channel are affected by weather conditions. weather conditions.

The high costs associated with this technology.

4. Wired technologies

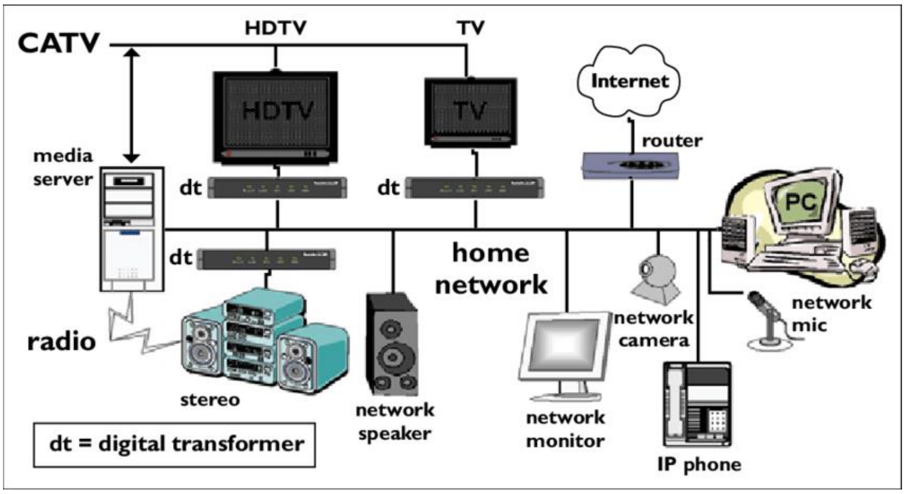

Figure 4. Wired Technologies [16].

In addition to wireless technologies, there are also wired technologies, which also have important advantages such as higher transmission speeds over longer distances and immunity to electromagnetic interference (see Figure 4). These advantages make this technology a good choice for use in high and medium voltage smart power grids.

4.1Optical fiber PLC (Power Line Communication)

Optical fiber has important characteristics that make it indispensable in the high-voltage environment, such as high bandwidth capacity and high immunity to electromagnetic interference and radio frequencies. The use of different wavelengths for simultaneous upstream and downstream traffic allows great flexibility in routing and switching optical signals. This is why fiber optics play a very important role in Smart Grid communication systems. Grid communication systems.

A very important aspect of smart grids is the use of a communication infrastructure with exceptionally low latency characteristics. The maximum latency allowed in a Smart Grid communication system is 6 cycles, or 100 ms. Therefore, the communication network supporting these scenarios must strictly respect this latency limitation. Optical fiber latency is less than 5 ms per kilometer length.

Although the cost of fiber optic installation presents a limitation, its communication infrastructure is very cost-effective due to its characteristics, which makes it a good choice in the high and medium voltage environment where distances are longer and electromagnetic radiation more intense. and electromagnetic radiation is more intense.

4.2PLC (Power Line Communication)

Power line communication is an old idea dating back to the early 1900s, when the first patents were filed in this field. Since then, utilities all over the world have been using this technology for remote metering and load control. PLC is a technology for transporting data over a conductor used for the transmission of electrical power, regulated under the IEEE P1901.2 and IEEE P1901.2 standard. IEEE P1901.2 and ITU-T G.hnem standard [12].

In Smart Grid many types of technologies can be used for communication but PLC is the only one that offers a lower cost in terms of infrastructure as the lines are already available. In addition, another advantage of using PLCs is that they allow communication between devices in different electrical installations by simply connecting to the power socket. by simply connecting to the power socket.

Unfortunately, PLC also struggles with the attenuation, noise and distortion problems encountered in RF (radio frequency) communications when communicating over power wiring because the power line was not originally designed for data transmission, [17] describes the following limitations that must be taken into account: - The power line is not designed for data transmission. following limitations that must be taken into account:

- Impedance variation and channel condition.
- White noise in nature.
- Attenuation corresponding to the frequency used.
- phase shift (single to three phase and vice versa) between indoor and outdoor architectures indoor and outdoor architectures

The most important PLC applications in the smart grid, at the high and medium voltage levels, will be explained below.

High Voltage: PLC technologies operating over high voltage AC and DC lines up to 1100 KV in the 40-500 KHz band allow data rates of a few hundred Kpbs and play an important role in high voltage networks due to their high reliability, low cost and long range [17].

Noise on a high-voltage transmission line is mainly caused by the corona effect (an electrical phenomenon occurring in the conductors of high-voltage lines and manifested in the form of a luminous halo around them) and other leakage or discharge events. Compared to medium and low voltage lines, high voltage lines are a better means of communication characterized by low attenuation. PLCs, in addition to providing connectivity, are also used for remote fault detection such as broken insulator, short-circuit insulator and cable break detection; and for determining change in height above ground of horizontal overhead conductors. high voltage overhead conductors.

Medium Voltage: An important aspect for the future of smart grids is the ability to transfer data on the state of the medium voltage grid where information on equipment and power flow conditions must be transmitted between substations within the grid. The materials used in the construction of the medium-voltage grid infrastructure are many years old, so fault detection and monitoring have become a very important aspect today.

Some applications of medium-voltage line communication are voltage lines are:

- Remote control for the prevention of island phenomena.
- Verification of the temperature of transformers.
- Voltage control on the secondary of transformers.
- Fault surveys.
- Power quality measurement.

5. Conclusions

In high and medium voltage environments, the requirements for communication systems are more demanding due to the coverage area and electromagnetic interference. Knowing the types of technologies available, as well as the applications and limitations of each, helps to make a fair comparison for the selection of the best technology depending on the application site. application site.

In addition to the technologies explained above, it is expected that IP protocol communication will be implemented to smart power networks, overcoming certain limitations by means of Middleware and QoS, so it is recommended to expand on this topic in future articles. future articles.

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