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GENERAL OVERVIEW OF AREA NETWORKS AND COMMUNICATION TECHNOLOGIES IN SMART GRID APPLICATIONS

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Abstract- Information and communication technologies (ICT) is a key factor in the development and efficiency of smart grids. Wired and wireless communication technologies are used for data transmission in Smart Grids (SG). These technologies vary according to the area networks either they used or the SG applications they are applied to. SG applications the functionality of each of the wired and wireless communication technologies is different. These functionalities can be the data rates they provide, the coverage areas, the applications they are used in, the advantages or disadvantages they provide. These features should be regarded when selecting a communication technology for SG applications. Power-Line Communication (PLC) technology is one of the wired communication technologies used in smart networks. The main advantage of PLC is that there is no need to install new communication infrastructures and the time and cost is less, Since the electricity transmission takes place over power line communication cables in the current electricity infrastructure and in addition to this, the cables to be used for PLC technology exist almost all over the world. PLC technology is the most basic candidate for SG applications, as it has the appropriate bandwidth to communicate in homes or rural areas. This article contains comprehensive descriptions of communication technologies in the smart grid. The data rates, range areas and applications of these technologies are explained and compared in detail. As a result of these studies, it is shown that PLC technology is a suitable and effective communication technology for smart grids.

Keywords: ICT, PLC, Smart Grid.

1. INTRODUCTION

The electricity grids have been using for nearly a century revolutionize almost every aspect of daily life. However, it becomes less efficient, with great difficulty meeting our ever-increasing needs. Therefore, a newer, more efficient, secure and flexible model of the existing network with storage, communication and decision-making features are needed. Basically, the electrical network consists of the interconnection of transmission systems. Smart grids, on the other hand, are the whole of the electricity network that emerges with the addition of production and deployment of transmission grids. The smart grid transforms the existing network into a more collaborative, responsive and organized network, and also has self-recognition and self-healing features to prevent security hazards or malfunctions under unexpected conditions [1].

Smart grids can:
1. Activates of consumers,
2. Provides production and storage option,
3. Enables new applications,
4. Delivers power quality,
5. Increases efficiency,
6. Corrects by predicting possible malfunctions,
7. Provides security and durability against external attacks.

Smart grids include different applications with the inclusion of consumers, service providers, operations and markets as well as generation, transmission and distribution.

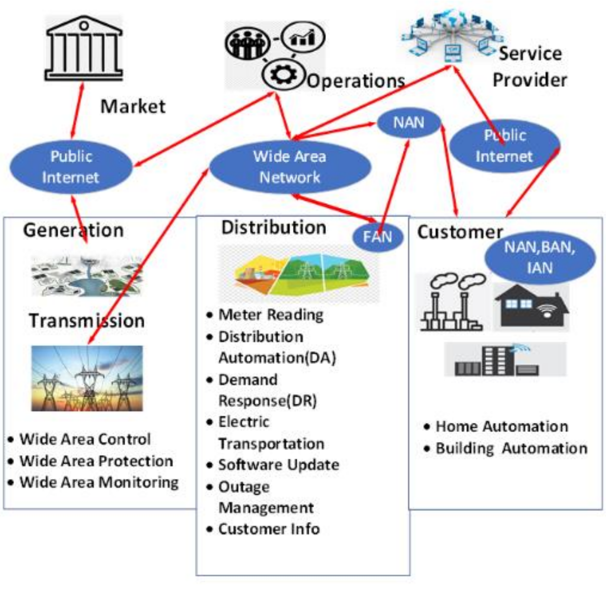

Figure 1. Smart grid communication area networks

Intelligent Grid communication comprises Home Area Networks (HANs), Building Area Networks (BANs), Industrial Area Networks (IANs) and Wide Area Networks (WANs). HANs is the node used by home devices to communicate. NAN dwell of numerous HANs. It transmits the measurement input to the input densifier and the control data to the HANs. WAN's task is to communicate with data centers. Existing meters in the HAN attach smart devices to each other and then attach to the portal. In NAN, measurement portal attaches to form a wireless network. WANs attach utility and distribution control systems to portal.

2. COMMUNICATION APPLICATIONS IN SMART GRID

There are many applications that can use HAN, NAN, or a consolidation of these networks. The US Department of Energy (DOE) stated that smart grid applications can be divided into subcategories [2]. Subcategories are hoped to have various QoS requirements such as high security, high reliability, bandwidth and latency. It is possible to increase performance in HAN, NAN and WAN by using cross-layer approaches. For all that, the describe of routing protocols is critical for supplying most applications' requirements.

2.1. Advanced Measurement Infrastructure

Advanced Measurement Infrastructure (AMI) provides bidirectional communication between smart systems and auxiliary systems. This infrastructure provides automatic visual reading of meters instead of the function known as manpower or meter reading [3]. This communication is realized by the combination of systems such as sensors, computer hardware and tracing system. The communication network obtained by AMI serves the combination and distribution of data. AMI is also an Information Technology (IT) infrastructure. Accessibility, number of customers, data rate and time delay are important factors in AMI's choice of communication technology. AMI usage also provides advantages such as reading cost, real-time consumption information, multi-service, multi-vendor service.

2.2. Demand Response

Demand Response (DR) system can instantly change the electric consumption depending on the loads in the distribution systems. Service companies supply Real Time Pricing (RTP) for customers. RTP adjusts customers' electricity usage according to the supply-demand balance. Hence, the existing power usage will be maximized and system efficiency will be increased. Utilities have some functions such as changing consumption time, reducing the likelihood of system failure and reducing cost. With these features, it can manage the power conditions in the network. Customers can plan their electricity consumption using smart devices that can communicate with smart meters through the management interface. In addition, customers also install Distributed Energy Sources (DEK) and energy holding gadgets in their areas to handle outgrowth electricity back [4]. DR systems need AMI infrastructure and area networks to achieve these features.

2.3. Electric Transportation

Renewable energy sources are very important as they prevent the use of fossil fuels as well as reduce pollution [5]. Fully charged electric vehicle (Plug-in Electric Vehicle-PEV) or plug-in hybrid electric vehicle (PHEV) attracts great interest from vehicle manufacturers in terms of the development of the infrastructure of zero-emission vehicles. Electric vehicles (EVs) use electrically rechargeable batteries in electric motors instead of using fossil fuels like other vehicles. In order to charge the EV's tank, a connection to the smart grid is required. This situation is valued as Grid to Vehicle (G2V) spill and can exist anywhere there are charging facilities. Also, there may be a situation such as Vehicle to Network (V2G) flow [6]. In this case, an EV is connected to the grid as needed and an electrical flow can occur from the vehicle to the grid. In this way, the smart grid can be fed from electric vehicles. Effective data communications are required to perform this exchange. The necessary communication can take place with HAN or NAN when the vehicle is connected to a station or parked.

Simultaneous charging of large numbers of clubfeet creates some difficulties. One of these difficulties is power. In the charging state, a lot of capacity will be required to the grid and to keep this load balanced, the charging times of the vehicles must be changed synchronously with the load or RTP signals on the grid. This also applies to V2G streaming. In order to use PEV batteries as feeders in case of high demand, electrical transport applications must contact with the PEVs and send their loading times and RTP data.

2.4. Distributed Energy Resources (DER) and Storage

In addition to generation, electric supply in smart grids is provided by distributed energy resources (DERs) in transmission, distribution and end-user systems. Connecting the DERs to the power grid is called mass generation. The traditional distribution grid has unidirectional power flow, which makes the deployment network very complex. DERs can store surplus electricity or energy from renewable sources for later use. In this case, DERs play an active role in both energy storage and making the supply-demand decisions of the end users. The stored energy can be used as substitute funs in the event of excess supply or power outages, to bolster DR changes or to sell the stored energy to the electricity market. HAN or NANs are needed to provide this type of communication.

Communication technologies propose a reliable and safe monitoring and control concept for DERs. For this, communication and information need to be standardized. The IEC 61850 standard has been augmented to include the tracing and manage of DERs.

2.5. Distributed Network Management

The existing distribution networks cannot be controlled and monitored manually due to their complex structure. A deployment management system (DMS) is needed to eliminate this situation and to report anomalies in the system. DMS is an Information and Communication Technology (ICT) based system for managing real-time network working. Data exchange in DMS is made possible by connecting to a WAN.

DMS is basically using Supervisory Control and Data Acquisition (SCADA) systems. Substations are monitored by SCADA, but SCADA data are not available in other systems, so manual coordination is required. DMS is needed to provide data exchange between creatures in existing distribution networks.

The most important requirements for DMS to provide total administration and overhaul functions for the deployment network and connected with real-time systems are reliable and seamless communication, strong integration capability and interoperability in real-time systems. Also, DMS needs 9.6–100 kbps bandwidth for reliable data communication and a delay of 100 ms to 2 s is required [2].

2.6. Wide Field Situational Awareness

Wide area situational awareness (WASA) defines as a range of technology integrations for power system monitoring and a general and dynamic protection for grid operation. WASA is the basic need to provide reliability, security and operability between a wide variety of connected devices in smart grids, as well as to solve a problem that threatens reliability and security in the event of an abnormality such as an interruption in the power supply. Considered as WASA technology, synchro phasors are responsible for measuring different mediums of the power system also facilitating comparison of some different in real time to provide an encryption of the entire power circuit at the same time.

WASA uses many technologies to transfer information. It gathers information for the current situation from transmission networks and electrical substations. This information is in milliseconds and very high frequency data. The collected grid is used to optimize the network devices and power grid interruption in a case of any problem. Information generally moves through NAN and WAN. Wide Area Monitoring Systems (WAMS) are divided into two: Wide Area Control Systems (WACS) and Wide Area Protection Systems (WAPS). WACS and WAPS extend broadband to provide scheduling demands [6].

3. HAN, NAN, WAN

A power layer that serves smart grids, power production, conduction, distribution, and consumer grids; a power check bed that includes smart grid tracing, control and administration actions; a communication layer providing bidirectional communication in the smart grid environment; Data privacy, data integrity, authentication and usability consists of a security layer and the application layer that considers applications to consumers and services, taking into account the data substructure.

The communication layer in smart networks, is one of the layers used in smart grid applications. This layer provides communication between applications or between smart devices and the customer. Communication is basically divided into 3 groups.

1. Home Area Network (HAN) / Building Area Network (BAN) / Industrial Area Network (IAN)
2. Neighborhood Area Network (NAN) / Field Area Network (FAN)
3. Wide Area Network (WAN)

Field networks providing contact for smart grid applications are determined according to their input transmission rates and the maximum distances they will ensure for communication. The summary of this divergence is presented in Table 1.

Table 1. Communication applications data rates and ranges

Communication Applications	Range	Data Rate
HAN BAN IAN	1-100 m	1-100 Kbps
NAN FAN	100 m - 10 km	100 Kbps - 10 Mbps
WAN	10-100 km	10 Mbps - 1 Gbps

3.1. Home Area Network (HAN), Building Area Network (BAN), Industrial Area Network (IAN)

HAN, BAN, IAN applications send information received from smart devices in home and indoor applications to the control in the customers' network. it also transmits the information received from the customer to smart devices. The use of high frequency is not required to transfer this data, and also all applications are carried out in residential / commercial / industrial buildings. For these applications, communication technologies need range up to 100 m and data rate up to 100 kbps are sufficient. These communication technologies can be ZigBee, Z-wave, PLC, Bluetooth and Ethernet.

HAN provides communications for home equipment. These equipment are home appliances that can send and receive signals from smart meters, indoor screens and home energy management systems. Home devices can send power readings for AMI implementation using HAN networks. It also enables HANs DR implementation and home automation networks for tracing and control implementations. BAN and IAN are used by customers for building automation, heating, ventilation, and other industrial energy management applications.

Communication for HAN, BAN, IAN is provided by wired technologies as it allows devices to be connected and disconnected flexibly and reduces installation cost. In addition, wireless technologies can be susceptible to interference from the presence of reflective surfaces in the home and various wireless device distributions.

3.2. Neighborhood Area Network (NAN) / Field Area Network (FAN)

NAN / FAN applications are used in implementations such as DR and deployment automation (DA). In smart grid implementations using NAN and FAN networks, data is transmitted bidirectionally from the customer to the substation or from the substation to customers. Thus, communication technologies that will provide a coverage area of up to 10 km and a data rate between 100 kbps - 10 Mbps are used in applications. These technologies are wired technologies and wireless technologies such as ZigBee, WiFi, PLC, Digital Subscriber Line (DSL), WiMAX, cellular or coaxial cable.

NANs provide communication between the building area network and WANs. Thus, the data collected from the customers in the neighborhood is transmitted to the electricity distribution companies. FANs are the state of NAN of smart electronic devices connected to field devices. FANs have low bandwidth and are suitable for reliable data communication. In addition to applications such as DR, DA, smart metering, load management, applications such as meter reading, electrical transport, firmware updates, customer information and messaging are also smart grid applications using NAN / FAN networks [7]. The choice of communication technology for these applications differs for FANs. While some electrical services prefer WiMAX, some choose fiber optic cables to get excellent communication achievement.

3.3. Wide Area Network (WAN)

WAN supplies transmission for smart grid spines, in addition to supporting real-time tracing, control and preservation practices that in order to avoid disruptions in the power grid. WAN applications provide a new opportunity to develop power system designing, execution and preservation in the smart grid. Examples of these practices are wide area tracing, wide area control and wide area preservation [8]. Wide area preservation supplies preservation to power systems to cope with power outages, transmission bottlenecks, or unexpected events that need a very short response time. Wide area control supplies self-betterment capability in excess of the functions provided by local control. Wide monitoring and detection are a communication network that provides high bandwidth and long-distance data transfer.

WiMAX and wired communications are the best communication technologies for WANs. As a result, the communication technologies to be used are selected depending on the cost and coverage area features.

Table 2 summarizes data rates and communication technologies for communication applications.

Table 2. Communication application requirements and technologies

Communication Applications	Data Rate Requirements	Communication Technologies
HAN	Usually contains low bitrate control information.	ZigBee, Wi-Fi, Ethernet, PLC
NAN	It depends on the density of nodes in the network.	ZigBee, Wi-Fi, Ethernet, DSL, Cellular, PLC
WAN	It includes high-capacity devices	Ethernet, Wimax, GSM, WLAN, Fiber Optic Cables

4. COMMUNICATION TECHNOLOGIES

The infrastructure of the current electricity network communication is defined as the contact network. In the smart grid, multiple network technologies are used in transmission, distribution and user areas. Before choosing contact technologies for applications, the application needs might determine and the needs should be analyzed for the technologies. In addition, the old communication infrastructure is insufficient to meet the smart grid applications where only the production and transmission parts are covered, and the capacity and data rate of the communication network are increasing. In addition, adding participants to the network or making changes to the network for additional communication network setup is difficult and costly.

Since each service unit in smart networks has different infrastructures and communication systems, there is no single communication technology for these applications. Smart grids are expected to have a mixed multi-layer network containing different technologies so as to supply confidential and efficient contact to network constituents. In this chapter, wired and wireless communication technologies will be considered and their properties such as bandwidth, data rates and range areas will be compared.

4.1. Wireless Network Technologies

Thanks to wireless network technologies, cables that allow devices to be connected in a wired way have disappeared. Wireless networks are disadvantageous due to their limited bandwidth and sensitivity to interference, as well as providing advantages in terms of setup and coverage. As a result of these disadvantages, it has low data rates and provides short distance connections. Each wireless network is divided into data rates and coverage areas. While 802.11 (WLAN) networks provide maximum throughput up to 150 Mbps, they are the most popular wireless network by ability a coverage area of up to 250 m, 802.15 (ZigBee) networks offer a coverage area of up to 10m with data rates between 20 kbps and 55 Mbps. 802.16 (WiMAX) networks, on the other hand, ensure an access range of 50 km with an input ratio of max 100 Mbps for broadband wireless internet access.

Communication technologies such as GPRS, Ethernet, IEEE 802.11, 802.15 and 802.16, known as wireless network technologies, are used in distribution areas.

4.1.1. Wireless LAN

Using IEEE 802.11 standards, Local Area Network (LAN) supplies point-to-point or point-to-multipoint contact with its robust, fast and high reliability features. Spread spectrum technology is used in IEEE 802.11. IEEE 802.11 is separated according to the modulation techniques it uses and the data rates they provide. 802.11a activates at a frequency of 5.4 GHz and applies Orthogonal Frequency-Division Multiplexing (OFDM) modulation. 802.11g is called advanced Wi-Fi, applies Direct-Sequence Spread Spectrum (DSSS) modulation technique and performes at a frequency of 2.4 GHz. These two standards supply input ratios of max 54 Mbps. 802.11b is called Wi-Fi and supplies a input ratio of 11 Mbps. IEEE 802.11i, also known as WPA-2, provides security in LANs [9]. 802.11n supplies input ratios max 600 Mbps uses Multiple-Input and Multiple-Output (MIMO) technology.

Wireless LAN setup provides various advantages as it is easier to install and cheaper than wired ones. The high reliability and usability that can be achieved by applying system design techniques is the increased message transmission security thanks to error correction algorithms. The disadvantages or difficulties of wireless LANs are; in high-voltage environments, electromagnetic interference slows data transmission, radio frequency interference can affect equipment, and equipment availability is limited [9].

4.1.2. WiMAX

Worldwide Interoperability for Microwave Access (WiMAX) technology is using IEEE standards 802.16. The main purpose of this technology is to ensure worldwide interoperability. The 802.16 standard was first published in 2011. According to this draft, a wide performance range of 10-66 GHz is defined for the communication substructure. In addition, frequency bands of 2.3, 2.5, 3.5 GHz are reserved for mobile communication, while 3.5 and 5.8 GHz frequency bands are reserved for constant contact. The 2.3, 2.5, 3.5 GHz spectra are licensed while the 5.8 GHz is unlicensed. Licensed spectra are used for long rages. WiMAX technology supplies a range of maximum 48 km and a input ratio of max 70 Mbps. Thanks to these advantages, the WiMAX technology becomes suitable for use with the Wireless Automatic Meter Reading (WMAR) system [10].

Besides the advantages of WiMAX technology, it also causes some difficulties. These are the cost of placing the WIMAX tower and the WiMAX frequency above 10GHz cannot pass through obstacles.

4.1.3. Cellular

The main advantage of cellular technologies such as Universal Mobile Telecommunications System (UMTS) and Long-Term Evolution (LTE) is that they offer wider coverage than other wireless technologies. 3G (3rd Generation), 4G (4th Generation), 4.5G (4.5 Generation) cellular technologies perform in the spectrum coverage of 824-894 MHz / 1900 MHz. While this technology offers a data rate in the range of 60-240 Kbps, its coverage areas vary according to the cellular service used. Cellular networks consist of cells formed by many small powerful wireless transmitters. Continuous data flow in cellular is provided by exchanging data from cell to cell. To make wired communication components wireless, data is received from the serial or ethernet interface and transmitted over the cellular network over another interface. In this way, this technology offers wide coverage and also there is no maintenance cost and the network is protected by the carrier [11].

Cellular technology has advantages and disadvantages over other technologies. Some of its advantages are; Since it was used in previous periods, it has no extra cost for installation, its coverage area is wide and its pricing is convenient, it has broad bandwidth. The disadvantages are network density or degradation in network account may occur in emergency cases and may not guarantee access in bad weather conditions.

4.1.4. ZigBee

ZigBee technology, built by the ZigBee Alliance, is uses the IEEE 802.15.4 standard and provides credible, convenient, low power consumption communication. ZigBee is commonly used in both commercial and industrial applications with its expanded network administration abilities. ZigBee technology works in 868 MHz, 915 MHz and 2.4 GHz frequency range using DSSS modulation and these are license-free spectra. It also offers data rate in the range of 20-250 Kbps with a range area of 10-100 m.

The access and charging time of ZigBee devices vary belong to topologies such as star, tree, and mesh. Besides, ZigBee uses 128 bit AES ciphering for safety. ZigBee technology is used in building automation, safety systems and AMI technologies.

Like other technologies, ZigBee in has its advantages and disadvantages. Being uses IEEE 802.15.4 protocol, it is also a good choice for measurement and energy administration. In addition, it is a proper communication technology for smart networks with its features such as its simplicity, low bandwidth requirement, low installation cost, easy network implementation and robustness [12]. ZigBee also includes functions such as load control, DR, real-time pricing programs for gas, water and electricity services. Contrary to these advantages, ZigBee in include low processing capabilities, small latency requirements and noise or interference that may occur due to sharing same transmission medium with different devices.

4.1.5. Bluetooth

Bluetooth is part of IEEE 802.15.1. This standard provides communication at short distances and low power. It labours in 2.4-835 GHz unlicensed and 1m - 100m coverage area and offers 721 Kbps data rate. Devices with Bluetooth figure comprise of 7-layer communication stack of Open Systems Interconnection (OSI), thus facilitating both point-to-point and point-to-multipoint communication. These devices may also interfere with the IEE 802.11-based wireless LAN network and be highly affected by communication links in the environment. Therefore, it offers a weaker security than other technologies [9].

As with other wireless technologies, Bluetooth technology has advantages such as low installation cost, mobility, wide coverage and fast installation compared to wired technologies. However, there are some difficulties for smart grid usage. Such as having interference / noise effects, low security.

Table 3 summarizes the data rates, coverage areas and smart network applications of wireless technologies [9].

4.2. Wired Network Technologies

As the name suggests, data communication takes place over power lines and is more preferred by service providers. It is preferred because of its reliability and sensitivity to interference. PLC is the most widely used technology among cable communications including PLC, Digital Subscriber Line (DSL), fiber optic and coaxial. While DSL provides data rate between 10 Mbps - 10 Gbps, coaxial or fiber optic cables can support data transmission between 155 Mbps and 160 Gbps.

Table 3: Wireless Technologies Data Rates, Range and Application

Wireless Network Technologies	Data Rate	Range	Smart Grid Applications
Wireless LAN	1-54 Mbps	100 m	Distribution preservation and automation
WiMAX	70 Mbps	40 km	WMAR
Cellular	60-240 Mbps	10-50 km	SCADA and tracing for distant distribution
ZigBee	20-250 Mbps	10-100 m	Directly load check of house appliances
Bluetooth	721 Mbps	1-100 m	Local online tracing applications

4.2.1. Digital Subscriber Line

DSL technology provides information conduction through telephone lines. Therefore, it avoids additional installation cost since it is connected to the control centers of electrical facilities. There are 3 types of DSL: Asymmetrical Digital Subscriber Line (ADSL), High-bitrate Digital Subscriber Line (HDSL) and Very-high-bitrate Digital Subscriber Line (VDSL). ADSL provides bi-directional communication with a download speed of up to 8 Mbps and an upload speed of max 800 Kbps. HDSL systems promote input ratios of max 2,048 Mbps for an interval of 3.6 km. Finally, VDSL provides fast input transfer max 100 Mbps [13].

DSL is a favorable applicant for smart grid plans as it is found in many facilities based on existing telephony services. However, the efficiency of DSL is inversely proportional to the distance, so the farther the customer is from the provider, the less efficiency will be. Also, the low power security and delay problems caused by DSL will not be suitable for the smart network.

4.2.2. Fiber Optic

Other wired communication technology used in smart networks is fiber optic communication that provides various applications such as transformer station automation and transmission field communication. Fiber optic technology, which supplies a data rate of up to 40 Gbps, is resistant to electromagnetic interference as well as transporting data packets to several kilometers. Fiber optic communication is considered as the basic contact technology for WANs because its data rate and sensitivity to rumble. Passive Optical Network (PON), which uses optical splitters to serve multiple customers of a single fiber, Wavelength Division Multiplexing (WDM), which uses the bandwidth found in optical fibers, and Synchronous Optical Networking (SONET) / Synchronized Digital Hierarchy (SDH) planned to transportation high-capacity traffic. These fiber communication types will be selected depending on the response times of the applications to be used and the service quality that the network can provide.

Fiber optic communication, which has higher capacity and bandwidth compared to other wired or wireless connections, enables an excellent Bit Error Rate (BER) performance, but front investment and maintenance costs are high [14].

4.2.3. Coaxial

Coaxial is based on cable television infrastructures and provides high speed data transfer. It is mainly designed for television and radio broadcasts. It is similar to DSL in the way it provides a connection from a supplier to the end user. Coaxial cable acts as a communication link between smart meters and an electricity deployment operator. The disadvantage here is that the connection slows down as the bandwidth is divided between many customers during the channel.

4.2.4. Power-Line Communication

PLC technologies use the available electrical substructure for communication. It makes use of electrical cables during communication. In this way, it reduces time and cost. PLC technology can provide data transmission in indoor and outdoor environments.

The use of PLC is based on 1800s [15]. In those years, it was mentioned that data could be transmitted over power cables and in 1918 Commercial Carrier Frequency (CaF) was started to be used over telephone lines. In the 1930s, it was used in LV and MV power lines by providing unidirectional communication at frequencies below 3 kHz. In 1976, the X10 was obtained by Piceo Electronics and was the preliminary trading plan to include PLCs. In the 2000s, the Open PLC European Research Alliance (OPERA) plan was created and this project aimed to improve and standardize PLC technologies and allow low-cost broadband access services.

The electricity grid can be considered the largest physical network, as there is access to electricity almost all over the world. Therefore, it is a fact that it has a high-capacity infrastructure. The main advantages of PLC technology since the availability of the substructure covering all countries, it can be counted as a decrease in cost and mobility, the ability to reach places where wireless signals cannot reach, information and system security, wide coverage area and high data speed. The disadvantages of PLC technology compared to other communication technologies are; It can be said that the power line parameters and the location of the loads connected to the grid change over time, impedance mismatches that may occur due to the fact that the electrical grid is not originally designed for data communication, signal attenuation and the Radio Frequency (RF) energy it carries can be spread due to its unprotected.

Table 4 summarizes the data rate, coverage area and smart network applications of wired communication technologies used in smart grids [16].

Table 4. Wired network technologies data rates, range and application

Wired Network Technologies	Data Rate	Range	Smart Grid Applications
DSL	14.4 Kbps	1-10 km	AMI, DR, HAN
Fiber Optic	170 Kbps	1-10 km	AMI, DR, HAN
Coaxial	348 Kbps - 2 Mbps	1-10 km	AMI, DR, HAN
PLC	75 Mbps	10-50 km (LOS) 1-5 km (NLOS)	AMI, DR

PLC systems are divided into 3 main groups according to data transfer bandwidth. These are Ultra Narrowband Power Line Communication (UNB-PLC), Narrowband Power Line Communication (NB-PLC) and Broad Band Power Line Communication (BB-PLC) systems.

UNB-PLC systems operate between the super low (30-300 Hz) and ultra low (0.3-3 kHz) bands [17]. UNB-PLC systems normally require additional connection circuits to reach customers due to low frequency, but can communicate over long distances thanks to MV / LV transformers.

UNB-PLC technology is based on the Two-Way Automatic Communication System (TWACCS) and Turtle standards. TWACS has been developed to provide two-way communication and provides communication over a range of more than 300 km in local areas. It also supports data transmission up to 100 bps at 50 Hz and 120 bps at 60 Hz [18].

NB-PLC systems perform in the frequency band between 3-500 kHz, which is in the Low Frequency (LF) (3-30 kHz) and Middle Frequency (MF) (300 kHz - 3 MHz) band range [19]. The X10 protocol for NB-PLC has been in use since 1978. This protocol planned for home automation by realizing data transmission at 20 bps speed and 150 kHz [20]. In addition, NB-PLC technology is preferred in energy monitoring and energy administration systems in homes.

NB-PLC systems have two types of standards, LDR and HDR. LDR systems can be used for residential automation, telemetry and outdoor lighting using Single Carrier (SC) modulation techniques. LDR NB-PLC systems offer a data rate below 10 kbps. HDR NB-PLC systems promote input ratios max 1 Mbps using OFDM techniques.

BB-PLC systems perform in the 1.8-250 MHz band, which is in the MF (300 kHz - 3 MHz), High Frequency (HF) (3-30 MHz) and very HF (30-300 MHz) bands [21]. It is suitable for applications requiring high data rate because it operates with high frequency. These systems offer data speeds up to 2 Gbps today.

Industry associations such as HomePlug Power Alliance (HomePlug), Universal Powerline Association, High-Definition PLC (HD-PLC) Alliance and HomeGrid Form have been established and the standards created by these are based on OFDM.

5. CONCLUSIONS

In this article, a detailed information is given for the applications of smart grids, area networks and communication infrastructures. It has shown that these applications and the networks used by these applications are very important for public services and customers to enable communication and data transmission between devices. For the development of SG communication technologies, device interoperability or the use of multiple technologies is required. For these, necessary situation can be achieved with the existing infrastructure without the need for a new infrastructure. In addition, the sensitivity of other technologies to noise or damping against obstacles is also all important matter to be analyses.

Considering all these, PLC technology is the most suitable component with its wide frequency range, bandwidth, data rate and high distance.

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