The principle of power line communications for home energy management system of smart grid technology in Thailand

Phatrakit Pisapan*, Wattanapong Rakwichian, Watchara Wongpanyo, Bunyawat Vichanpol and Chatkaew Chailuecha

School of Energy and Environment University of Phayao 56000, Thailand
***Corresponding author's email:** tanpitor@gmail.com
Received: 04/01/2017, Accepted: 18/01/2018

Abstract

Smart grid technology is an energy revolution of the world in the era of globalization which is a result of communication and information technologies developments that can serve the data responds quickly, accurately, anywhere and anytime. Smart grid technology has been extensively studied and developed worldwide with awareness of energy security, energy demand and global climate change. Consequently, the concept of technology integration between communication systems into the electrical system has been innovated to manage and control the use of electricity more efficiently, reduce energy loss and does not destroy the environment to save the world. A smart grid is an intelligent power network that combines many kinds of future technologies together such as renewable energy, electric vehicle, smart meter, smart home and smart phone and can communicate with each other in the network with the strategy of demand response management. Power line communication technology is the best one of data communication technology for the smart grid infrastructure in Thailand which can be used with an existing power grid without more investment in new grid installations. In addition, PLC technology is applicable for the large power system as generation system, transmission system and distribution system. Furthermore, it is suitable for using to develop the control system for household appliances in a home area network which is the key success factor for developing a smart home. However, the communication between control unit and electric devices can cause real time monitor, measurement and control the system this will result in efficient energy consumption management.

Keywords:

Smart grid technology, communication and information technology, power line communication (PLC), home area network (HAN), demand response management, home energy management system (HEMS)

1. Introduction

Smart grid technology emphasizes the development of management for all parts of electrical networks to achieve higher efficiency power consumption and minimize loss in the system. The energy management system is a key of the systems control. And a demand response is the main variable to control the quantity of appropriate power generation sufficient for consumption at different time periods. The power quality [1] is an important variable to control energy loss in every part of the system from harmonic distortions, short circuits and faults in the power system. Thus it is important to know the location of the faults to improve these electric systems promptly. The entire system is controlled via communications and information technology in different ways and the communication technologies need to be selected that are appropriate to the type of electricity grid.

These communication technologies can support the applications to control the operation of the electricity grid such as the generating system, transmission system, distribution system and utilization system which are based on the amount of data to be sent through the system, communication range and installation costs.

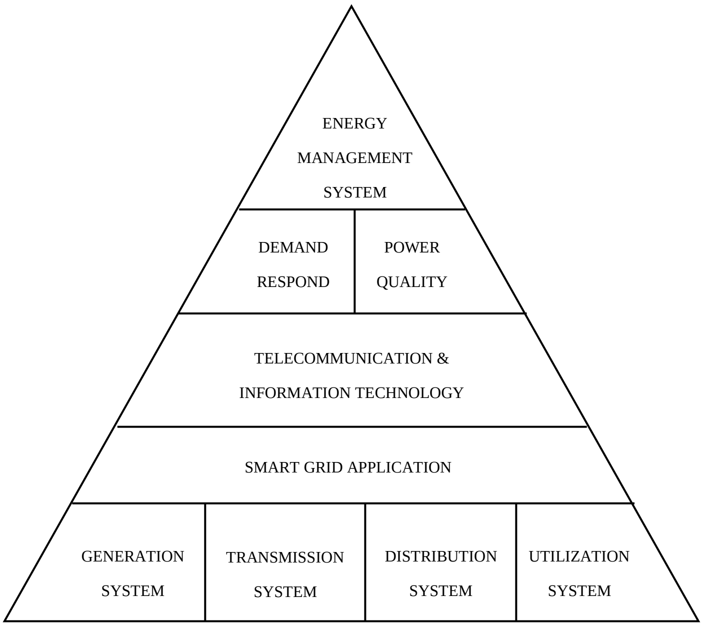

Fig. 1 The structure level of a smart grid technology.

The structure level of the smart grid technology (figure 1) shows that at the top of the pyramid is the Energy Management System (EMS) which is the most important part of the system. The EMS's functions are control and management which must depend on the data from the demand response and power quality. The data of demand response will indicate the need of the energy in various periods of the user. The data of power quality will support the decision of selecting the energy source. In the middle of the pyramid is an infrastructure for data communication. The telecommunication technology and information technology will be integrated in each power system and operate via application. Therefore, the communication technology must be selected to applicably integrate with the power system which has different conditions as shown in the below of the pyramid.

Energy management systems [18] can be divided into categories according to the type of use and the boundary range of an electricity grid. The smallest area of the energy management system is the home energy management system (HEMS). HEMS will manage the various electrical systems within the boundaries of a residence behind an electricity meter which is the part of users. They can manage the power utilization by themselves, such as the power generated from a PV rooftop or wind turbine can be controlled by using demand response management and can be set conditions follow to the electrical using behavior or the lifestyle of power users.

The power management will control the electrical energy which is produced from sources within the HEMS system before requesting power from external sources. Therefore, a concept of the zero net energy can reduce the cost of energy for the household with sustainable energy. And they can rely on themselves if a disaster or force majeure makes electricity inaccessible from the outside grid. This system also includes a multi-family residential property, as well as condominiums, apartment and residential complexes.

Building Energy Management Systems (BEMS) [18] has more complex because this system is used to manage the energy for various buildings, such as government buildings, shopping centers, office buildings, universities and hospital buildings. The amount of energy and diversification of electricity energy using are more. There are many various (only use 1 of these – your choice) sources of electricity generation such as solar energy, wind energy, biomass and also there are backup generators in a system. This management system also has several variants, such as different periods of use and different quantities of the electricity demand. It may be difficult about power quality from various parts of the system.

A Factory Energy Management Systems (FEMS) [18] has management conditions that are the same as a HEMS that homeowners manage by themselves but there are more energy demands and the impact of power quality is bigger, because the factory's machinery generate harmonic currents and faults in the electrical system. Therefore, it needs to have a detailed design for the power quality control system. Furthermore, factories can install renewable energy systems because there are very large rooftops for installing photovoltaic panels on the building's rooftop with power capacities in MW. The above three energy management systems are located under the Community Energy Management Systems (CEMS) [18]. This system is designed for power users who can rely on themselves from the household level to the community level and extended coverage in the province and neighboring areas.

Which it can cause reducing power generation of the country and will good result in the reduction of fuel imports from abroad, reduction the loss of electric power in long distance power transmission system, reduction the budget to install power transmission system and reduction the problem of the environment that caused by large power plants that use fossil fuels as a coal.

2. Literatures review

The literatures in this paper mention the concept of Power Line Communication (PLC) for the Energy Management Systems (EMS) on a smart grid network. The PLC is probably the best communication technology for smart grid systems in many applications which was discussed with a lot of researches. Ronnie and Sunguk (2015) [1] studied power line communication for a smart micro grid with Advanced Metering Infrastructure (AMI). The various characteristics of the smart grid and PLC technology are analyzed for use in conjunction with the internet networks. The smart grid applications with the communication infrastructures will be used to control and monitor the electrical system. Smart grid communication infrastructure can be classified as Home Area Network (HAN), Neighborhood Area Network (NAN) and Wide Area Network (WAN). There are many technologies, including cellular networks and PLC which are competition for smart micro grid communication. This article discusses power line communication for smart micro grid as Narrowband PLC, which is one that competes in the right technology for micro grid networks. However, Broadband PLC is still considered for advanced communications for various smart grid applications.

Derya and Tankut (2015) [5] studied the applications of new power line communication model for smart grids. There are the comparative studies of communication technologies for smart grid application in terms of wire and wireless technology. It found that wired communication as a power line communication, has many advantages such as the cheaper cost of investment, works well with existing infrastructure, wide coverage area, high data capacity and security. It has developed a power line communication model for smart grid applications with transmitting data over the existing electrical network infrastructure by simulating in Matlab Simulink.

The simulation results show that effective communication is the best communication technology. It is important to develop a smart grid system. This article examines the behavior of PLC technology for applications with a smart grid. It uses different PLC system models to simulate and test in a factor of attenuation that influences performance such as different cable lengths or output voltage amplitudes. The overhead low and medium power transmission lines were tested by limiting the length of cables. The simulation results of the PLC system are derived from different cable lengths for transmitting and receiving in medium voltage and low voltage wires. According to the simulation results, the transmitting on medium and low voltage on different PLC models is compared. In the second PLC model showed the best attenuation values of the transmissions for power line communication applications in the medium voltage (MV) transmission line.

Lars, Andreas and J.Joaquín (2012) [8] studied the power line communication for the various applications of the smart grid. It found that although the PLC technology has a very strong competitor, both wired and wireless communication. The power line communication technology will complement the various communications to develop the smart grid system as PLC will naturally upgrade from conventional conductors to hybrid and bidirectional power systems and data communication solutions. One of the key advantages of PLC is full control over physical media, without the need for third party providers, such as telecommunications companies or mobile operators.

Thus, Ronnie and Sunguk show that Narrowband PLC is the right technology for micro grid networks. Derya and Tankut demonstrated that the power line communication application in the medium voltage (MV) transmission line has the best attenuation values of the transmissions. Lars, Andreas and J.Joaquín found that PLC has full control over physical media without the need for third party providers. Although PLC studies for smart grids have been conducted from the aspects of difference applications. The result shows that PLC technology is effective and economic for every application.

PLC is a powerful technology for data transmission with various communication techniques. Aderemi, Adeyemi and Yury (2012) [2] examined the physical layer model of Powerline Intelligent Metering Evolution (PRIME) by studying the standards of communication technologies, especially PLC communication which is a full duplex communication for data transmission via electrical power line in the electrical network. PLC technology is used to read the advance meter and to control the home automation. PRIME is a new NB-PLC system, which uses OFDM in its physical layer for the last mile of communication. This study focuses on the performance of PRIME data is modulated with DQPSK and 4-QAM in the four (4) channels and aims to explore several PLC technologies classified based on the operating frequency range. Larry, Jose, Kaywan, Lorenzo, Srinivas, Hidayat, Pascal, Raffaele, Daniel and Andreas (2012) [10] studied the HomePlug AV2 Technology. This article introduces the entire system architecture and technical key to improving the quality of HomePlug AV2 and it has been suggested to improve at the layers of PHY and MAC. The results show the achievable data rate and coverage of the HomePlug AV2 have significant benefits.

In this paper, we intend to conduct a literature review to acknowledge the properties and problems of PLC technology for smart grids. Stefano, Anna and Zhifang (2011) [6] studied the role of the power line communication in a smart grid. This gives an overview of what makes PLC possible today by exploring the history and description of the latest advances in technology. The situation of the PLC applications within the Smart Grid such as sensor network and the problem of network control have been analyzed in detail because the necessary ingredients of network planning are modeling. Furthermore, they have created two engineering models. The first modeling is the PLC channel pattern through fading model. The first aspect is modeling the PLC channel through fading models and the second is checking for smart grid control and traffic patterns which this helps to achieve better understanding of communication needs. Finally, the study in this article is a study of the electrical system and the properties of the topology of the distribution network. The topology study of electrical networks is very important for PLC networks because the power grid is not the only source of information but it is also a unique data transmission system when the PLC is used in a smart grid.

Massimo, Andrea and Fabio (2012) [7] have studied the impedance of the best signal receiver for the optimization of SNR in broadband PLC. The front-end of the receiver device is designed for broadband power line communications by focusing on the design of the input impedance that made the maximum value of the signal-to-noise ratio (SNR) at the receiver. It shows that the amplitude of the received signal is an important part for the communication. It also shows that the impedance of the receiver affects the amplitude of the interference term by focusing on the background noise and provides a description of the interference at the port of the PLC network receiver. The noise pattern is the sum of four uncorrelated parts, namely the active noise, resistive noise, receiver noise and coupled noise components. They have studied the impedance design problem for the real home network and evaluation by experiment. The results of this measurement are described and the statistics of the best impedance are reported.

Amilcar, Pascal, Michel, and Ahmed (2012) [9] studied Radiation Mitigation for Power Line Communications using Time Reversal. This article was first introduced in the application of TR (Time Reversal for Wireless Transmission) to reduce EMI (Electro Magnetic Interference) caused by the wired communication system. The test results show that in the medium as power line TR can extend the transmission channel between 1 dB and 7 dB and a TR filter can significantly reduce EMI values for 60%. In addition, research will focus on the study of TR values at higher frequencies and other mediums, such as DSL lines.

In their studies, Stefano, Anna and Zhifang found that data transmission with PLC technology is probably a problem in a smart grid system because there are several data sources. Massimo, Andrea and Fabio show that the amplitude of the received signal is an important part for the PLC because the signal will be attenuated with various impedances. Amilcar, Pascal, Michel, and Ahmed demonstrated that Electromagnetic Interference (EMI) is the problem of power line communication in the smart grid system.

3. The electric power system of Thailand

The electric power system of Thailand has 3 main service providers which are the Electricity Generating Authority (EGAT), Metropolitan Electricity Authority (MEA) and Provincial Electricity Authority (PEA). There is only one agency EGAT, which is responsible for the production and supply of energy resources to produce enough electricity to operate and maintain the power plants in the country, high voltage transmission lines, substations and distribution of electricity to the MEA and PEA includes large industrial customers.

MEA has the duty to service and distribute power in Bangkok and surrounding provinces (Nonthaburi, Samutn Prakan) and maintain transmission lines, substations, distribution lines, distribution transformers and low volt distribution lines, with purchasing electricity from EGAT 69 KV, 115 KV and 230 KV. The PEA has served as the MEA but only in the provinces and purchased electricity from EGAT in sizes of 11 kV, 22 KV, 33 KV, 69 KV and 115 KV.

The power system in Thailand consists of four systems as follows, the generating system, transmission system, distribution system and utilization system. For the generation system in Thailand the production volume is divided by type of power plant as follows, from Thermal 3,674 MW, Combined cycle 9,210 MW, Hydropower 3,448 MW, Diesel 30 MW, Renewable energy 40 MW, and also purchases of power from private sources and from abroad as well as the number of 24,721 MW. In total, EGAT can supply electricity either from self-produced and purchased a total of 41,097 MW. The electricity from a generating will be elevated to high voltage and then sent into a high-voltage transmission system with 500 KV, 230 KV, 115KV and 69 KV. The substation serves to reduce high voltage to medium-voltage and sent into the distribution systems, which MEA has medium-voltage at 12 KV and 24 KV and will be converted to low-voltage at 416/240 V, PEA has medium-voltage at 22 KV and 33 KV and will be converted to low-voltage at 400/210 V and then will be sent into the utilization system. Details are given in Table 1.

Table 1 the electric power system in Thailand.

<table>
<tr><th>Generation</th><th colspan="4">Transmission</th><th colspan="3">Distribution</th><th>Utilization</th></tr>
<tr><th></th><th>HV Transmission Line</th><th>Substation</th><th>HV Sub-transmission Line</th><th>Substation</th><th>MV Distribution Line</th><th>Distribution Transformer</th><th>LV Distribution Line</th><th>End User</th></tr>
<tr><td colspan="9">EGAT - Electricity Generating Authority of Thailand</td></tr>
<tr><td rowspan="4">Thermal
3,647 MW
Combined Cycle
9,210 MW
Hydropower
3,448 MW
Diesel
30 MW
Renewable Energy
40 MW
Total
16,376 MW

Purchase
24,721 MW
Grand Total
41,097 MW</td><td rowspan="4">500 KV
230 KV</td><td rowspan="4">500 / 230 KV
230 / 115 KV
115 / 69 KV</td><td colspan="6">MEA – Metropolitan Electricity Authority</td></tr>
<tr><td>230 KV
115 KV
69 KV</td><td>230, 115, 69 KV
to
24, 12 KV</td><td>24 KV
12 KV</td><td>24, 12 KV
to
416 V</td><td>416/240 V</td><td>3P 416 V
1P 240 V</td></tr>
<tr><td colspan="6">PEA – Provincial Electricity Authority</td></tr>
<tr><td>115 KV
69 KV</td><td>115, 69 KV to
33, 22 KV</td><td>33 KV
22 KV</td><td>33, 22 KV
to
400 V</td><td>400/230 V</td><td>3P 400 V
1P 230 V</td></tr>
</table>

4. The communication technology for smart grid

The data communication between systems in the network of power grid is an important part of a smart grid system. This allows the controller to know the working status of the system is normal or fault and will be able to correct and improve the system better quickly. The data communication network of electrical grid information for smart grid [3] can be divided into three levels as follows. Home Area Network (HAN) works to communicate and control devices within the home area. Neighborhood Area Network (NAN) is for the control and surveillance of the quality of the utilized electricity grid through a smart meter and Wide Area Network (WAN) is for the control and monitoring of the network of electrical power systems [6] in the generating system, transmission system and distribution system. Each network will use different communication technology to suit different applications.

Table 2 the relation of the communication system and smart grids technology.

Network	Type	Communication	Standard	Frequency (MHz)	Bandwidth	Technology/ Modulation	Range (m)	Application
HAN	W	BB-PLC	HomePlug GP1.1 HomePlug AV2 ITU-T G.hn (9960,61) IEEE P1901	2-30 1.8-86 1.8-250 1.8-50	10 Mbps 2,024 Mbps 500 Mbps 556 Mbps	OFDM/QPSK OFDM OFDM OFDM	200 200 200 1,500	Smart Grid Internet, HDTV VOIP
		Ethernet	IEEE 802.3	RJ45	25 Gbps	CSMA/CD	30	Internet
	WL	Wi-Fi	IEEE 802.11n	2,400-2,500 4,900-5,900	200 Mbps	OFDM-MIMO	100	WLAN
		Bluetooth	IEEE 802.15.1	2,402-2,480	720 Kbps	FHSS	10	Cable Replacement
		UWB	IEEE 802.15.3a	3,100-10,600	110-1,600 Mbps	OFDM	4-20	Wireless Video
		Zigbee	IEEE 802.15.4	868-868.8 902-928 2,400-2,485	20 Kbps 40 Kbps 250 Kbps	DSSS	10-300	Monitoring Control
NAN	W	NB-PLC	G3-PLC PRIME ANSI/EIA709.1.2 ISO/IEC 14543-3 KNX IEC 621334 ITU-TG.hnem (9955,56) IEEE P1901.2	35.9-90.6 KHz 42-89 KHz 86, 131 KHz 125-140 KHz 60-76 KHz 34.4-478.1 kHz 35.9-487.5 kHz	2.4-34 Kbps 21.4-128.6 Kbps 3.6-5.4 Kbps 1.2 Kbps 2.4 Kbps 821.1 Kbps 207.6 Kbps	OFDM OFDM BPSK S-FSK S-FSK OFDM OFDM	10-100,000	AMR Smart Grid
WAN	W	Fiber Optic	IEEE 802.3av	SM-Fiber	10,000 Mbps	CSMA/CD	20,000,000	WWAN
	WL	CDMA 1x EV-DO	ITM-2000 3GPP 2	400, 800, 900, 1,700, 1,800, 1,900, 2,100	3.1 Mbps	TDM/CDMA	1,600-8,000	Mobile Phone WWAN
		WCDMA HSDPA	ITM-2000 3GPP R6	1,800, 1,900, 2,100	14 Mbps	CDM-TDM/ CDMA	1,600-8,000	Mobile Phone WWAN
		LTE-Advance	ITM-2000 3GPP R10	700, 850, 900, 1,800, 1,900, 2,100, 2,500	1,000 Mbps	OFDMA	1,600-8,000	Mobile Phone WWAN
		Fixed WiMAX	IEEE 802.16d	11,000	75 Mbps	OFDM	6,400-9,600	Fixed WMAN
		Mobile WiMAX	IEEE 802.16e	2,300, 2,500, 3,300, 3,500, 3,700	30 Mbps	TDM/ OFDMA	1,600-4,800	Portable WMAN
		Mobile WiMAX2	IEEE 802.16m	6,000	600 Mbps	OFDMA	1,600-4,800	Portable WMAN

Table 2 shows the communication technology for smart grid is there many types to choose from the wired and wireless technology.

Such as HAN has the power control and a management system for generating, utilization and storage. The system will communicate with the appliances in a home. There are many communication technologies that support this application, such as Broadband-PLC, Ethernet, Wi-Fi, ZigBee and Bluetooth [2]. For NAN the communication technology is NB-PLC, which is supported by several international standards as G3-PLC, PRIME, ANSI/EIA709.1.2, ISO/IEC14543-3 KNX, IEC 621334, ITU-TG.9955, 56, IEEE P1901.2 [6]. They are most focused on developing applications for smart grids and smart metering to measure the amount of electricity consumption remotely. WAN is a very wide network remotely. Therefore, communication used optical fiber, cellular and Wi-max for SCADA applications to control and monitor the power system for monitoring power quality, stability and reliability of the electric power system. This is the communication technology for the smart grid, in addition to the applications and the coverage area, also it should be considered suitable for the data rate and latency. [3, 6]

5. Power line communication for smart grid

Power line communication technology in the early era has been studied and patented for the first time in the United States in 1894. With the concept, that the signal of a telegram is transmitted into a power line system. Then there are the interests and development to be used for telemetry since 1922 by an electric utilities agency with electrical equipment manufacturers and using carrier frequencies in the range 15-500 kHz to input to a high voltage transmission line. Later in the years 1930 - 1940 there is a ripple carrier signaling to use with the power distribution in medium voltage 10-20 kV and low voltage 240/415 V. In 1970, Tokyo Electric Power Company succeeded in experimental use of the remote meter reading systems and about the year 1985 there was a study on the introduction of digital communications and digital signal processing for transmission via power lines. The results that came out are satisfactory.

Currently, PLC technology has received widespread attention and many standard supports from both Europe and America. Applications can be developed and used in various applications. PLC technology was classified according to the use frequency to three types.

5.1. Ultra Narrowband Power Line Communication (UNB-PLC)

Ultra-narrowband Power Line Communication is the technology used at lower frequencies 3 KHz and the data transmission rate at 100 bps with the communication range is up to 150 Km. UNB-PLC communications with low data rates and short coverage distance should be used to communicate information for automation equipment such as automatic meter reading (AMR) or control devices in the home. [3, 4]

5.2. Narrowband Power Line Communication (NB-PLC)

Narrowband Power Line Communication is used with frequency range 3-500 MHz and data rate about many hundred bps. Although NB-PLC data rates are low, the noise and attenuation of signal are low. There has been a lot of interest to study and develop from institutions around the world and it set up a standard. There is the frequency band for NB-PLC standard as shown in Table 3 below:

Table 3 A frequency bands for NB-PLC. [3-5]

Region	Institution	Frequency	Application
Europe	CENELEC (European Committee for Electrotechnical Standardization)	A: 3 - 95KHz	Utility Service
		B: 95 - 125 KHz	Any Application
		C: 125 - 140KHz	Home Networking
		D: 140 - 148.5 kHz	Alarm / Security
U.S.A	FCC (Federal Communications Commission)	10 - 490 KHz	
Japan	ARIB (Association of Radio Industries and Business)	10 - 450 KHz	
China	EPRI (Electric Power Research Institute)	3 - 90 kHz 3 - 500 KHz	

Table 3 reveals that many standard organizations have defined a feature of the physical and medium access control layer of NB-PLC. Such as G3-PLC, which was released by the ERDF and Maxim in 2009, use the frequency range 35.9-90.6 KHz at a maximum data rate of 35 kbps and uses OFDM technology is a major to integrate signal with DBPSK and DQPSK in term of time. It is designed to work with smart grids for medium voltage and transformer with noise and high signal attenuation therefore G3-PLC is a low data rate.

PRIME (Power line Related Intelligent Metering Evolution) [4] was formed in 2010 by the PRIME Alliance, with Iberdrola and Texas Instruments. It used a frequency of 42-89 KHz at a maximum data rate of 128.6 kbps and uses OFDM technology with DBPSK, DQPSK and D8PSK in terms of the frequency. PRIME is designed for smart metering from the beginning for working through a low voltage network. Both 3G-PLC and PRIME use the frequency band of the CENELEC A.

There are also new standards developed for NB-PLC, they are IEEE1901.2 and ITU-T G.hnem with ITU-T G.9955 (Physical Layer) and G.9956 (Data Link Layer) is designed for various applications for smart grids. Both of standards support power line communication in low voltage, medium-voltage and transformers with transmission rates up to 500 kbps.

KNX (EN 50090, ISO/IEC 14543) [4] is a standard that is designed for intelligent building (HBES: Home and Building Electronic Systems). That resembles a home and building automation. The protocol of the communication network is OSI-based. KNX which is also the recipient and collect the three standards that came out earlier together is The European Home Systems Protocol (EHS), BatiBUS, and the European Installation Bus (EIB). KNX standard is administered by the Konnex Association. Whose members are electrical equipment manufacturers and related many as 348 companies in 37 countries.

ANSI/EIA 709.1 [5] is the standard for home control and building automation, industrial, communications and utilities infrastructure and work on the protocol, LONWORKS (Local Operating Networks).

5.3 Broadband Power Line Communication (BB-PLC)

Broadband Power Line is a technology for high-speed data communications at a frequency of 1.8-250 MHz for home networks and multimedia.

In early 2000 industries configured and released BB-PLC.

There are several standards, such as the family of HomePlug and the most widely used is HomePlug AV [3, 8] with data rate 200 Mbps to support multimedia applications such as HD Video / Audio. Later developments and expand access to higher data transmission rates up to 1 Gbps, which is the standard of HomePlug AV2 (Next Gen Multimedia Networking) [8]. There are also standard HomePlug Green PHY for use in energy management, and control applications with electric vehicles.

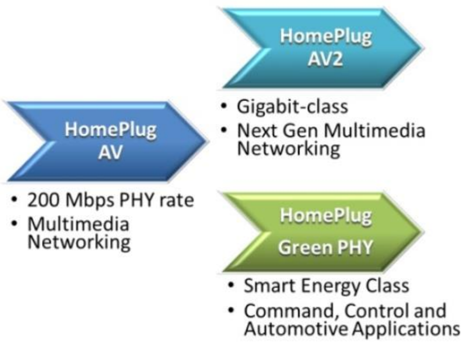

Fig. 3 HomePlug technology evolution @ HomePlug Powerline Alliance, Inc.

ITU-T G.hn (G.9960, 61) is a standard for Home Network, which is the ITU-T G.hn standard for all types of wired communication technologies for homes and buildings, such as powerline (PLC), a telephone line and coaxial cables with data rates up to 1 Gbps, making BB-PLC can support high data rates for data communication, but the transmission distance is limited to only about a hundred meters

IEEE1901 standard for BB-PLC supports two modes of BB-PLC is the first OFDM of scheme PHY/MAC which is consistent with the properties of HomePlug AV and the other is wavelet OFDM of the pattern of PHY/MAC compatible with HD-PLC. IEEE1190.1 standard can transfer data up to 200 Mbps [3, 9].

These three features of the BB-PLC using conventional of CDMA/CA MAC (Medium Access Control) and OFDM technology have a very similar direction but do not support collaboration. All of these features, are designed for HAN networks. BB-PLC technology is best suited for HAN networks.

6. Technique of the energy management system for home and building in smart grid system

Previously the circuit breaker is an absolutely essential device and has most important safety mechanisms in a building. Whenever electrical wire has too much current flowing through it, the mechanism will cut the power until somebody can fix the problem. But today, the world has developed many innovative technologies such as computer, telecommunication, information technology, and the production technology of a modern electronic device. So we can make and develop the electrical circuit control to work in a completely automatic, which the system can turn on or turn off automatically from the data processing by itself or by command from the remote control.

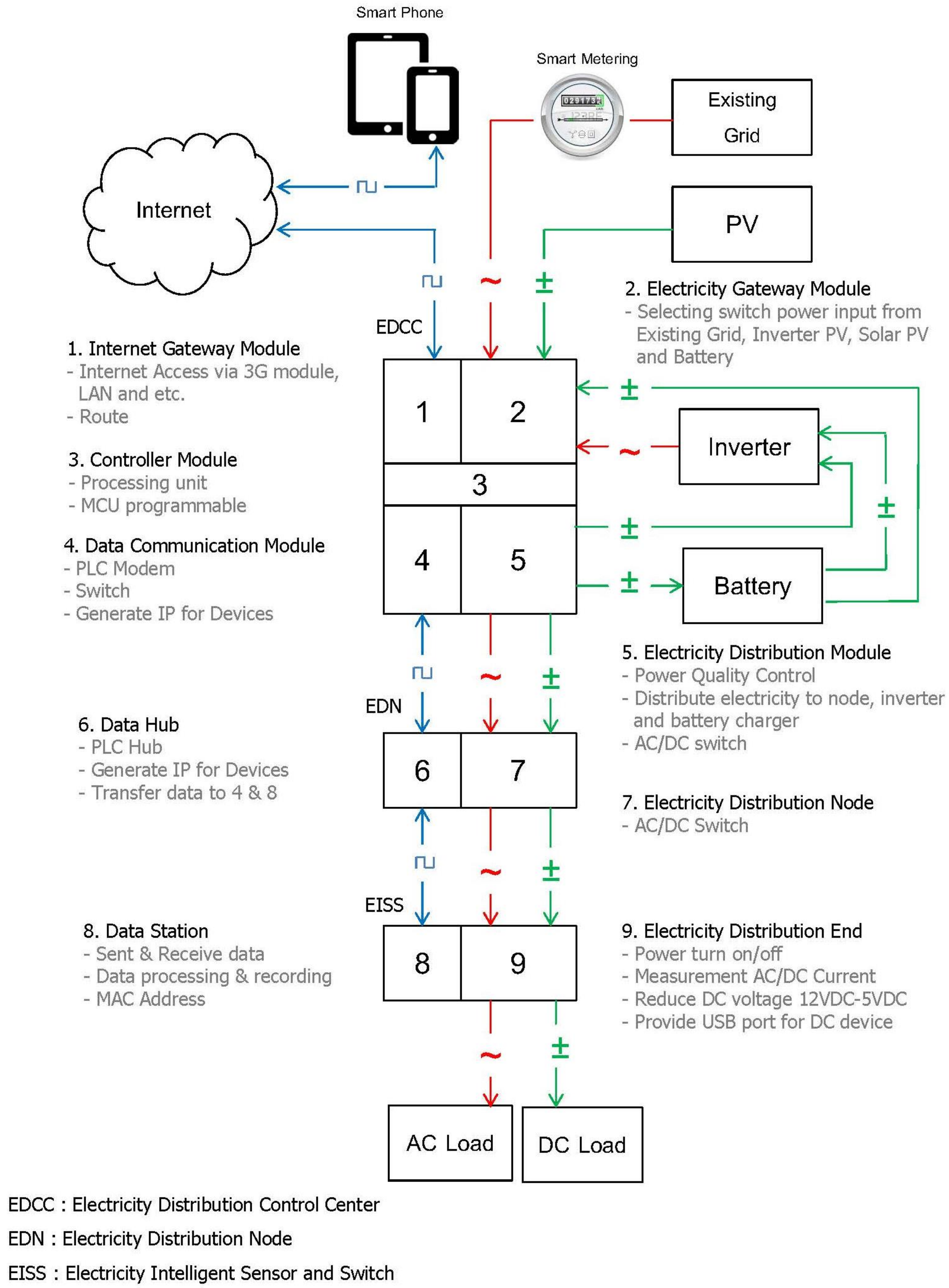

Fig. 4 Configuration of power and energy management system for smart grid building.

The electrical circuit control system for a smart home building consists with the electricity distribution control center (EDCC), which it will control the import and export of the electric current of AC and DC power for loads and communicate the data and command between intelligent sensor device and external control device as a smart phone and tablet. The operation of system starts from the electricity gateway module (EGM), which is the power interface of a system. It controls electricity input from all power sources such as from the external grid of the electricity provider via smart metering or from internal power generation sources such as DC power from rooftop photovoltaic (PV) and AC power from inverter. The system will check first completeness and accuracy of the electricity current by power quality control unit before transfer current to electricity distribution module (EDM). It will distribute current to the requested destination loads or cut the power follow a command. All working will be processed by the processing unit module. There is a function for deciding whether to import or export the electric power with the data of power usage in a building from data communication module. It communicates between main control unit and intelligent sensor unit, was connected with destination load to know the quantity of power usage in each device. The remote control from outside of the building must communicate through the Internet Gateway Module which is the internet access with various methods as LAN, WiFi and 3G/4G mobile phone.

For the control of destination electric device, the device must connect to the power distribution equipment, which is an active type. It is called the intelligent sensor unit. This Intelligent sensor unit can communicate any data and command with the centralized control unit and can measure any electrical values of the electric device and reply these data to a controller. And also to open or close the electric circuit, when it received the command from a controller. This intelligent sensor has identification code as a form of IP Address that was created from a data communication module. It will make all electrical equipment to be like a computer in LAN network. And data transmission is encrypted format frame data to be able to recognize the details of the received information, for example. Where does it come from? What is the equipment? What is the electricity format? When is it running? And how much amount of electricity used?

For the orders to turn on and turn off a device, the system will know what the device is required. These data are passed into the used AC lines in regular building with the power line communication technology (PLC). The master equipment in this network is a PLC switch, it controls the receiving and sending of the frame data between ports within the network and creates identification code (IP Address) for the destination equipment at the intelligent sensor unit and shares bandwidth or data rates on the network. The PLC switch is connecting the data to various nodes before connecting the terminal device. These nodes have the PLC hub for distributing the data to various ports in a network. It is the center of the connection between nodes and makes these various nodes can communicate with each other by installing the hub at the center of a star topology in the network. Each node that took part in the network will connect through a hub and will communicate by sending information via this hub.

The connection between intelligent sensor unit and electrical load is the key factor to make a smart home to be a perfect system. Whether the device that use an electric DC or AC power before it starts working, the intelligent sensor system will detect the properties of the electrical equipment, that is DC or AC and will command to distribute the electric power follow the kind of requested power, 240VAC or 12VDC. If the device needs 5VDC power the intelligent sensor will supply 12VDC into the voltage reduction circuit to adjust voltage down to 5VDC for a USB port to suitable application requirements. While all electrical devices are running, the intelligent sensor unit will transmit the data of power using into the processing unit all time. The processing unit will know the electricity consumption of the past and know that the demand for electricity using in the future which can make predictable that how much electricity will be used in the next 10 hours.

The processing unit will control the power generation and power management follow the demand response with Home Energy Management System (HEMS) which is algorithm of the data communication in terms of the conditions restricting the use of energy as needed of load devices inside a building and can monitor and adjust power usage accordingly from remote control by smartphone and tablet. This will enable electrical consumers to engage with the automation of the electrical energy management in the buildings. The electric power storage and import are prepared to make sufficient and appropriate for the needs will happen with algorithm of the demand response management (DRM) of a smart home building. Which makes everything is automated.

7. Conclusions

The evolution of the communication technology and information technology contributes to give development of the conventional electric power grid system to the smart grid system that can control and manage automatically. There are many international engineering standards to support the applications of smart grid system. The right one communication technology for smart grid is a PLC technology which can transmit data over power lines, even if it is an existing grid. The PLC technology has several formats and several standards which based on an application and the distance of the network. A suitable technology for remote network control and automatic meter reading is the UNB-PLC. For the controlling of the household appliances within a house most use the NB-PLC technology but for multimedia and short distance the suitable technology is BB-PLC.

Smart home technology is a part of smart grid. Smart home's status is the load, which different from traditional load, because load as a smart home can communicate with IT and can be the power generating building or be a negative load. The power storage is both supply and load. It will be stored when the electricity is oversupply or cheaper and will be distributed when the electricity is expensive or insufficient. Grid connection between the buildings for exchange the electric energy will become the micro smart grid which can communicate and control the energy distribution for the electric devices within a smart home as required. Smart home technology is one of the smart grid systems and moreover, is also a key technology in the push for the use of smart grid technology more widely. It is closer to the actual users and can be done before large scale network system.

References

[1] Stephen, F., & Bush. (2014). Smart Grid Communication-Enabled Intelligence for the Electric Power Grid. IEEE Press. John Wiley and Sons.

[2] De1rya, B.U., & Tankut, Y. (2015). Applications of New Power Line Communication Model for Smart Grids. *International Journal of Computer and Electrical Engineering*.

[3] Ronnie, D., Caytiles., & Sunguk, L. (2015). A Survey of Recent Power Line Communication Technologies for Smart Micro Grid. *International Journal of Software Engineering and Its Applications, 9*(2), 251-258. Retrieved from http://dx.doi.org/10.14257/ijseia.2015.9.12.22

[4] Aderemi, A., Atayero, A.A., Alatishe., & Yury, A. Ivanov, Members, IAENG (2012). Power Line Communication Technologies: *Modeling and Simulation of PRIME Physical Layer. Proceedings of the World Congress on Engineering and Computer Science*, 2.

[5] Stefano, G., Senior Member IEEE, Anna S., Fellow IEEE, & Zhifang W., Member IEEE. (2011). *The role of power line communications in the Smart Grid. Proceedings of the IEEE*, 99., 6.

[6] Massimo, A., Andrea, M., Tonello, & Fabio Versolatto (2012). A Study on the Optimal Receiver Impedance for SNR Maximization in Broadband PLC. *Hindawi Publishing Corporation Journal of Electrical and Computer Engineering*, 20., 13, Retrieved from http://dx.doi.org/10.1155/2013/635086

[6] Lars, T.B., Andreas, S., & Joaquin, J., Escudero, G. (2012). Power Line Communications for Smart Grid Applications. *Hindawi Publishing Corporation Journal of Electrical and Computer Engineering*. Retrieved from http://dx.doi.org/10.1155/2013/712376.

[7] Amilcar, M., Pascal, P., Michel, N., & Ahmed, Z. (2012). Mitigation for Power Line Communications Using Time Reversal. Hindawi Publishing Corporation. *Journal of Electrical and Computer Engineering*. 2013., 11. Retrieved from http://dx.doi.org/10.1155/2013/635086.

[8] Larry, Y., Jose, A., Kaywan, A., Lorenzo, G., Srinivas, K., Hidayat, L., Pascal, P., Raffaele, R., Daniel M. S., & Andreas S. (2012). An Overview of the HomePlug AV2 Technology. Hindawi Publishing Corporation. *Journal of Electrical and Computer Engineering,* 2013., 20, Retrieved from http://dx.doi.org/10.1155/2013/892628

[9] Md. M.R., Choong, S.H., & Sungwon, L., Kyung Hee University. Jaejo L. Korea Electrotechnology Research Institute, Md. Abdur Razzaque and Jin Hyuk Kim, Kyung Hee University (2011). *Medium Access Control for Power Line Communications*: An Overview of the IEEE 1901 and ITU-T G.hn Standards. IEEE Communications Magazine.

[10] Panagiotis, D., Diamantoulakis., Vasileios, M.K., & George, K.K. (2015). Big Data Analytics for Dynamic Energy Management in Smart Grids. *Elsevier* Retrieved from http://dx.doi.org/10.1016/j.bdr.2015.03.003.

[11] Berger, L. T., & Iniewski, K. (April 2012). Smart Grid - Applications, Communications and Security. *John Wiley and Sons*.

[12] Dostert, K. (1997). Telecommunications over the Power Distribution Grid- Possibilities and Limitations (PDF). Proc 1997 Internat. Symp. on Power Line Comms and its Applications: 1–9.

[13] Qing-Chang, Z., & Tomas, H. (2013). Control of Power Inverters in Renewable Energy and Smart Grid Integration. IEEE Press. *John Wiley and Sons*.

[14] Peter, Z. (May 2008). *Use of Electronic-Based Power Conversion for Distributed and enewable Energy Sources*. ISET-University of Kassel.

[15] Broadridge, R. (1989). Power line modems and networks. Second IEE National Conference on Telecommunications. London UK, 294–296.

[16] ITU Telecommunication Standardization Bureau Policy & Technology Watch Division. (April 2010). *Activities in Smart Grid Standardization Repository*. Retrieved from http://www.itu.int/dmspub/itu-t/oth/18/01/T18010000020002PDFE.pdf.

[17] Brown, P. A. (September 1999). Power line Communication – Past Present and Future. In Proceedings of the International Symposium on Power Line Communication and Its Applications (ISPLC).

[18] Teng-amnuay, Y. (2015) Energy Management System HEMS, BEMS, FEMS, CEMS and Renewable Energy. Retrieved from http://www.pointthai.net

[19] Kitisittichai, P., & Aruninta, A. (2015). Best Management Practices for Sustainability in a Small-Scale Community Renewable Energy: Sathya Sai School Thailand. *Applied Environmental Research*, 37(2), 93-105.