Research on Development & Key Technology of PLC

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Abstract

PLC, the power line carrier communication is a kind of technology which utilizing existing low-voltage distribution network power line as a transmission channel to achieve long-distance exchange of wire and cable data communications[1]. PLC used carrier to transmit analog or digital signals with a high speed. Power lines are the most extensively covered networks in the world and are widely used in power system protection, terminal information collection, production command and dispatch. This paper will discuss the development and key technology of PLC.

Keywords

PLC, Power line, Carrier, transmission channel, long-distance, high speed.

1. Introduction

The idea of using power lines to communicate was born very early. In 1838,Edward Davies's idea of using PLC to monitor the unmanned voltage level of Liverpool in London through remote-controlled ammeters marks the beginning of an exploration of PLC technology. In the 1920s, some well-known international companies and research institutes started to gradually develop PLC technology. In 1958, Texas Instruments and Fairchild Semiconductor invented integrated circuits for power line carrier communication firstly. Intel introduced the first low-power PLC microprocessor in 1971. At the February 2000 DEM200 conference, Intellon, a leader in powerline communications, demonstrated a high-speed PLC technology chip for residential networks with communication rates up to 1Mbps. With the development of power line carrier communication technology, some industry leaders such as Texas Instruments, Intellon, Spain DS2 and Germany Polytrax have emerged, and more than 90 domestic manufacturers including the above enterprises (Home Plug Alliance, HPA) in 2001 developed the first PLC technology standard HomePlug 1.0[2,3]. 2004 Spain DS2 pioneered the 200Mbps broadband PLC chip. In 2009, the G.hn protocol introduced by the International Telecommunication Union (ITU) raised the theoretical transfer rate of the PLC to 1 Gbps.

The domestic research on PLC technology started relatively late, but it has also achieved some stage results. In order to develop PLC terminal equipment suitable for our unique low voltage distribution network structure, in 1999, China Electric Power Research Institute firstly launched the basic research of power line communication system. On the basis of previous studies, according to China's terminal products introduction of power line carrier modulation chip developed the first set of 2Mbps communication rate released in 2000, and passed the acceptance test in 2001, established the first broadband power line pilot areas, to achieve the family of high speed PLC data communication. In 2003, the latest PLC system developed by our country has raised the transmission rate to 45Mbps, and established the first pilot area of the country's first 45Mbps full power line broadband Internet access. By 2006, the Beijing power line broadband access test network covered more than 500 pilot plots and about 4000 buildings. In 2012, the state power grid affiliated enterprises developed the first BPLC core with independent intellectual property rights in China.

2. Power Line Carrier Communication Principle

2.1 Low Voltage Power Line Channel Characteristics

The power line is a non-uniform distributed channel. Compared with the power line network structure and clean channel abroad, the power line channel environment in China is more complex.

(1) Time-varying System

The power line channel will directly connect to all kinds of users' load, while the random access or offline switching of terminal load, and the random switching of network structure will lead to the strong time-varying signal of channel interference.

(2) Noise Interference

Power line as a transmission channel, its noise interference is complex and strong. In addition to the background noise from the distribution network, the periodic noise caused by the access load, there are also narrow band noise and sudden noise.

(3) Signal Attenuation

Because of complex and time-varying load, PLC communication terminal output impedance and channel input impedance are difficult to match, and the resulting signal reflection and harmonic attenuation will attenuate communication signals. The higher the frequency of the communication signal, the longer the transmission line is, the attenuation of this signal will be enhanced[4].

2.2 Key Technology of Power Line Carrier Communication

The signal modulation method directly determines the performance of the power line carrier communication, such as the quality, reliability and so on. After a long time of development, modulation technology adopted in low voltage power line carrier communication has developed from traditional frequency shift keying and phase shift keying to spread spectrum communication technology and orthogonal frequency division multiplexing technology.

(1) FSK(Frequency Shift Keying)

Frequency shift keying, also known as digital frequency modulation, will transform the baseband signal to A/D, and then use the digital baseband signal to modulate the carrier frequency. The information carried by the discrete digital signal will react to the discrete change process of the carrier frequency. The binary system commonly used two different frequency carrier said digital signal "0" and "1", "0" corresponds to the carrier frequency, "1" corresponds to the carrier frequency, the two carrier modulated signal can be added to obtain the final frequency shift keying signal, the initial phase of the carrier is zero. The time domain expression[5]

$$S_{2FSK}(t)=[\sum a_n g(t-nT_s)]\cos(\omega_1 t)+[\sum \overline{a_n} g(t-nT_s)]\cos(\omega_2 t) \quad (1)$$

$g(t)$ is unipolar rectangular pulse width, and

$$a_n=\begin{cases}0, \text{probability is } P\\ 1, \text{probability is } 1-P\end{cases} \quad (2)$$

The principle block diagram of FSK modulation and demodulation is shown below

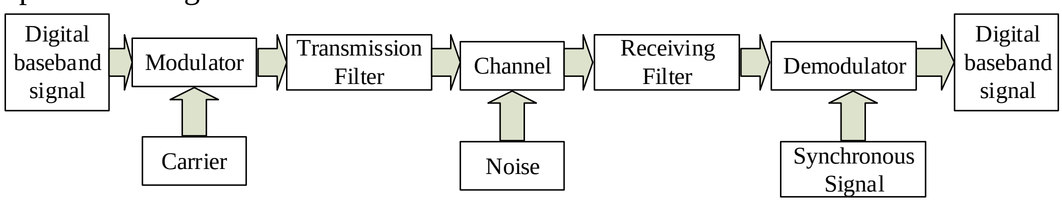

Fig. 1 The principle block diagram of FSK modulation and demodulation

In order to improve the bandwidth utilization of the PLC channel, the FSK system restricts the signal bandwidth by sending a filter. The receiving filter is used to filter out of band noise to improve the signal to noise ratio of the received signal and to match the transmission filter and channel characteristics to avoid intercode crosstalk. The demodulation method of binary frequency shift keying includes three kinds of coherent demodulation, non coherent demodulation and zero crossing demodulation. The coherent demodulation has the strongest anti-interference ability, but it needs to synchronize the carrier signal at the receiving end, and the system is complicated and difficult. The non coherent demodulation uses envelope detection and does not need to synchronize the carrier signal, and it is easy to realize. Zero crossing detection is a common and simple demodulation method by detecting the change of the number of zero points to realize the change of the carrier frequency[6,7]. FSK system can better adapt to the line impedance and interference changes of low voltage power line, with low complexity and easy implementation, but its transmission efficiency and spectrum utilization rate are low, and it is only suitable for short-range low-speed data transmission.

(2) QPSK(Orthogonal Phase Shift Keying)

Orthogonal phase shift keying (orthogonal phase shift keying) is a kind of digital modulation with high frequency spectrum utilization and strong anti-interference. It is also widely used in low voltage power carrier communication. The PSK uses the phase change of the carrier to represent the binary data stream. The BPSK system uses a signal element to represent a bit data, and its output phase shift is just π. The phase of the QPSK signal is moved to a multiple of $\pi/2$, and each signal element represents two bit data. Figure 2 is a block diagram of the QPSK modulation principle[8].

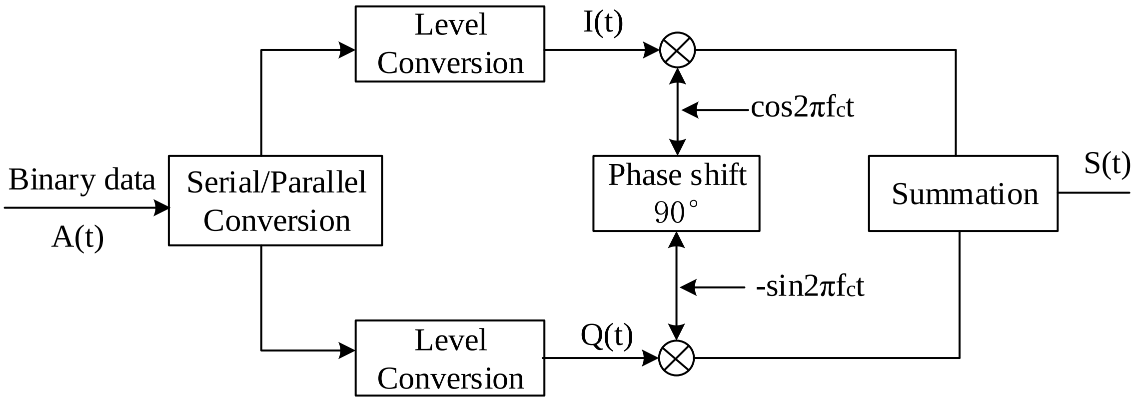

Fig. 2 The Block diagram of QPSK modulation principle

Orthogonal phase-shift keying specifies four kinds of carrier phase to represent two bits of data, and binary digital signals form two independent equal length bipolar pulse signal streams $I(t)$ and $Q(t)$ to modulate the same phase carrier $\cos(\omega_c t)$ and orthogonal carrier $\sin(\omega_c t)$ respectively after serial to parallel conversion and level conversion. The final QPSK signal can be obtained by superposing the two BPSK signal streams after the modulation, and the general form is:

$$S_{QPSK}(t) = I(t)\cos(\omega_c t) - Q(t)\sin(\omega_c t) \tag{3}$$

In the application of power line carrier communication, QPSK modulation has many advantages, such as strong anti-interference, high frequency band utilization and fast transmission speed compared with 2FSK, which has been widely applied.

(3) DSSS(Direct Sequence Spread Spectrum)

Direct sequence spread spectrum (DSSS) technology is one of the commonly used technologies in low voltage power line carrier communication system. DSSS technology expands the spectrum of useful signals through high speed pseudorandom spread spectrum code sequence, and then uses the same pseudo random spread spectrum code sequence at the receiver to despread and expand the original signal. The principle block diagram of direct sequence spread spectrum (DSSS) is shown below.

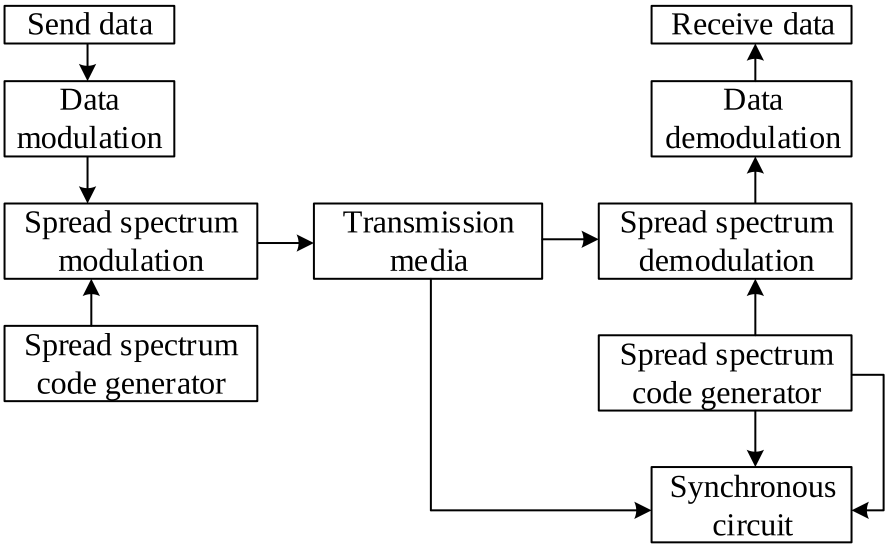

Fig. 3 DSSS principle block diagram

The Shannon formula shows that the signal bandwidth W is inversely proportional to the signal-to-noise ratio P / N, that is, in the spread spectrum communication, it can transmit a signal with a low signal-to-noise ratio due to its large bandwidth and has strong anti-interference ability, high communication rate, low power spectral density, easy code division multiple access and other advantages[4].

(4) OFDM(Orthogonal Frequency Division Multiplexing)

Orthogonal frequency division multiplexing (OFDM) is a multi carrier transmission technology that transfers high-speed serial data streams to multiple low speed sub streams and modulates them to multiple orthogonal sub carriers simultaneously. Each subchannel can be seen as flat fading and subcarriers orthogonal to each other, thereby eliminating intercode crosstalk and intercarrier interference[9,10]. OFDM can be modulated and demodulated with fast Fourier transform (FFT/ IFFT). The principle block diagram is as follows.

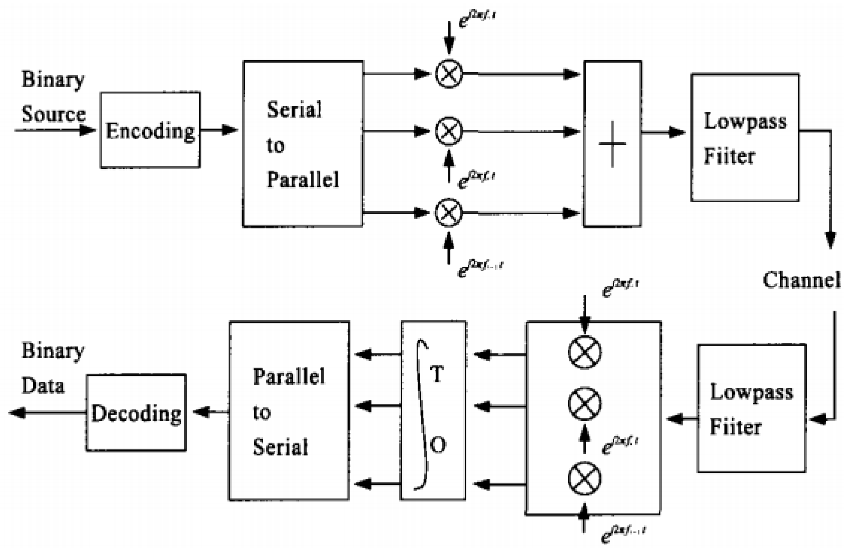

Fig. 4 OFDM principle block diagram

OFDM can make full use of band bandwidth, the signal spectrum is very close to the rectangle, its bandwidth utilization is close to the theory limit of Shannon information theory[11]. OFDM technology has the advantages of high frequency bandwidth, strong anti-interference ability and high transmission rate, so it is widely used in low voltage power line communication system.

3. Conclusion

The above four commonly used power line communication technologies have their own advantages and disadvantages. In order to cope with the complex power line channel environment and ensure the reliability of data transmission, the most widely used technology is PLC chip of OFDM technology.

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