Research on Power Consumption Information Acquisition System Based on Broadband Power Line Carrier Technology

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Abstract. At present, the broadband power line carrier communication technology is developing continuously. It has the advantages of improving the real-time, stability and reliability of acquisition, and it can carry out unified comprehensive management of the distribution power communication network, so it has a more extensive application prospect. This paper analyzes and compares the mainstream communication technologies of the current power consumption information acquisition system, discusses the advantages and disadvantages of various communication technologies, and discusses and analyzes the application prospect of broadband power line carrier communication technology.

1. Introduction
At first, power carrier communication was used in 10kV distribution network. For this reason, the international standards organization has stipulated a series of standards. The carrier frequency band is mainly distributed in 3-500kHz.

In 2003, the carrier meter reading has entered a rapid development period. With the development of physical layer modulation / demodulation and error correction technology of power line carrier communication and the improvement of semiconductor integrated technology, the anti interference ability of large-scale power line carrier communication integrated circuit adopting complex digital signal processing technology has been greatly improved compared with previous generations of products.

Since 2005, several large carrier chip manufacturers in China have started the product research and development with the network neuron chip as the core, which has been comprehensively improved from the physical layer, network layer, link layer, etc., and solved the physical layer communication support ability of any node and the network transmission agreement with relay control [1,2].

In recent years, new manufacturers are in line with the international standards. OFDM multicarrier technology, such as prime and G3, has been gradually promoted on the spot. Broadband carrier technology is preferred, with the frequency range of 2-12 MHz. Modern communication technology is applied in the field of power consumption information collection.

2. Analysis of Channel Characteristics of Domestic Low Voltage Power Line
Low voltage power line is not specially used to transmit communication data, its topology and physical characteristics are different from traditional communication transmission media, such as twisted pair, coaxial cable, optical fiber and so on. Power line communication is to transmit high-speed data information on the path loaded with power frequency power signal, so it has the
characteristics of bad working environment, serious noise interference and time-varying. At the same time, the signal is easy to produce reflection, standing wave and harmonic phenomena, which makes the attenuation characteristics of the signal extremely complex, resulting in the power line communication channel has a strong frequency selectivity [3,4].

There are few domestic power network management systems, which are seriously polluted, and the power quality is not fully guaranteed. Therefore, there is a high demand for reliable meter reading of domestic power lines. The specific impact is as follows:

1. The distribution transformer has a barrier effect on the power carrier signal. Generally, the carrier signal can only be transmitted in the area of one transformer, but there is cross transformer common zero line crosstalk, which will make the signal between multiple transformers close to each other.

2. The loss of power carrier signal is different due to different signal power routing methods, which include "line to ground" and "line to zero". The "line to ground" mode has a loss of more than 10 dB less than the "line to zero" mode, but the "line to ground" mode is not suitable for all regional power systems.

3. Strong pulse interference of power line itself.

4. The interference of background noise is serious, and there is no conventional mode, and the variation is very large. The noise generated by resistive, inductive and capacitive loads and high-power and low-power loads is superimposed on the power grid, which has a serious impact on the signal.

5. The carrier signal has high attenuation in power line transmission. When the load is heavy, the line impedance is small, resulting in high attenuation of carrier signal. For example, when the power line is empty, the carrier signal can be transmitted for several kilometers, but when the load is heavy, it can only be transmitted for tens of meters. Therefore, it is necessary to further improve the carrier signal power to meet the transmission requirements, but it is not advisable to increase the volume and power consumption.

6. The power line can deform the effective signal. The first mock exam is that the power line is a distributed parameter network. The different points have different effects on the data signals. At the same time, the power lines are always changing and the time variant is strong, so it is difficult to ensure the carrier communication effect in accordance with the unified mode.

3. Limitations of Micro Power Communication Technology

Compared with the narrow-band carrier scheme, the effect of communication is greatly improved. However, the characteristics of the scheme are still limited to achieve the goal of "full acquisition". Due to the influence of building shelter, the micro power concentrator can not cover the whole platform area. The usual solution is to install multiple concentrators in one platform area. This solution can achieve the full coverage effect, but it increases the difficulty of construction and maintenance, and intensifies the dependence of the other company on the subsequent services provided by the manufacturer; The access rate is greatly affected by the climate, especially in thunderstorm days and when the humidity is a little high; the micro power wireless can only read meters after networking, but in the process of reading meters, the whole network lacks the whole network maintenance mechanism, which mainly reads meters on the basis of the "old network" every day, usually 20:00-23:00 at night for special network maintenance; However, if the key nodes of the whole network are disturbed during the day, the overall network's access rate will be greatly affected, and the access rate will fluctuate greatly; because of the use of common frequency points, it is easy to be affected by other signals. In order to avoid cable TV, reading is only done between 0 and 6 o'clock every day. For the module with standard transmitting power of 50 MW (17 DBM), the effect of reading on site is often poor. The manufacturer will often increase the transmission power to 20 DBM to achieve good results; some key nodes need to replace the external antenna module, but the safety is reduced, vulnerable to persecution, and the antenna lead is long, so it is very difficult to construct on site.
4. Analysis of the Advantages of Broadband Carrier Communication Technology

4.1. How to Achieve the Goal of "full acquisition"

The "full acquisition" function of strong smart grid focuses on "full". Full understanding, not only for the replacement of non-intelligent meters on the network, but also for the equipment that has been replaced can be all on the network, can read stably for a long time, can respond to the call test of the master station at any time, and can actively report abnormal events continuously.

First of all, let's look at the most widely used narrowband carrier scheme, which uses residential low-voltage power line as the transmission medium, FSK or BPSK single frequency carrier technology, and the center frequency is below 500K. The communication quality mainly depends on the impedance and noise characteristics of the power line. The carrier frequency band used in the narrowband scheme has a natural disadvantage in impedance and noise [5-7].

Compared with the narrow-band carrier scheme, the micro power wireless solution has a great improvement in the effect of transceiving. However, the characteristics of the scheme are still limited to achieve the goal of "full acquisition". Due to the influence of building shelter, the micro power concentrator can not cover the whole platform area. The usual solution is to install multiple concentrators in one platform area. This solution can achieve the full coverage effect, but it increases the difficulty of construction and maintenance, and intensifies the dependence of the other company on the subsequent services provided by the manufacturer; The ventilation rate is greatly affected by the climate, and is seriously affected by thunderstorm days and slightly high tide humidity [8].

Table 1. Key technical characteristics of broadband communication

| Key technologies of broadband carrier | Problems solved |
|--------------------------------------|-----------------|
| Communication frequency band selection and adaptive technology | Field noise and impedance mainly affect the frequency band below 1 MHz |
| OFDM Technology                      | Effectively deal with multi-path reflection, inter code crosstalk and pulse noise interference |
| Anti noise technology                | To solve the typical noise of narrow band and pulse in power line; to filter out the out of band noise and different phase noise |
| Anti channel attenuation and load change technology | To solve the frequency selective fading under the influence of channel attenuation and impedance characteristics of PLC |
| Automatic fast networking technology | The typical 300 scale network is completed in 3 minutes, and the average time for a single device to enter the network is 30 s. Minimize the impact of networking on services and improve the real-time performance of the system |
| Dynamic adaptive multipath routing technology | The real-time response time of typical 300 scale route is less than 1 min, and it supports multiple paths and broadcast technology. Meet the cost control index |
| Multi network automatic coordination technology | It can solve the cross-talk of multiple areas, and the concentrator of multiple areas can work adaptively and coordinately. It supports parallel meter reading and real-time cost control |
| Polyphase Technology                 | Effectively isolate the influence of multi-phase load and noise superposition |

The key technical characteristics of broadband communication are shown in Table 1. The technology determines the best signal transmission frequency according to the frequency selection characteristics. By using effective anti noise technology and anti attenuation technology, the communication performance of power line is greatly improved, and high-speed, reliable and real-time long-distance
Communication is realized. In order to achieve the goal of "full cost control", it is necessary to build on the basis of "full acquisition", which greatly increases the requirement of real-time communication. It is no longer a communication requirement for a fixed period of time, but a communication guarantee for any time. On one hand, the success rate and communication time of cost control depend on the stability of physical layer communication. On the other hand, it also depends on the number of retransmissions, that is, the real-time adaptability of the system to channel changes. Due to the time consuming in GPRS communication and the increase of retransmission times, the overall service time consumption has increased dramatically. However, broadband technology has completely improved the impact of retransmission times to ensure the true realization of the goal of "full acquisition" and "full cost control". [9,10]

4.2. How to Solve the Crosstalk Problem of Multiple Variable Signals in Broadband Carrier Communication

The problem of crosstalk in the station area has been puzzling the narrowband carrier scheme. Because of the isolation effect of the transformer, the communication signal is attenuated to a great extent. The signals between stations still affect each other through parallel line crosstalk, ground wire, space radiation and other ways. Especially in some new high-rise residential areas, with the increase of the number of households and the power consumption of each household, multiple transformers are generally used in the same machine room for power supply. This design intensifies the crosstalk between stations. For narrow-band equipment, there is no effective solution mechanism. Crosstalk near the station area is the same frequency interference for the signal in the station area. Because of using the same frequency, this kind of interference can not be eliminated, and can only rely on the system's own back off mechanism to avoid. As a result, in the case of multiple stations, the reading quality drops sharply compared with that in the case of only one station.

The broadband carrier scheme adopts the automatic coordination technology, as shown in Figure 1. It does not need manual intervention to keep the meter reading running continuously. The automatic coordination technology of network ID is to define the unique ID of the network, generate it randomly, dynamic coordination of conflicts, and ensure the independent operation of the network; It has a real-time and dynamic bandwidth coordination mechanism, which ensures the success rate of communication according to the influence degree of crosstalk. It supports frequency division and time division schemes. The service layer is not aware of it. It can continuously read meters in real time, and it can support the coordination of multiple stations; The unique white list technology refers to defining the white list through table files, supporting the stable operation of the station area, not cross entering the network across the station area, configuring the network identifier (SNID) and setting the white list to divide the subnet. For the access requests sent by the nodes not in the white list of the network, the concentrator carrier module refuses to join, and informs the node of the reason for rejection. The node judges by itself The network access request is sent to other networks, and the network coordination between the concentrator carrier modules is carried out to avoid conflicts and mutual interference. Each node only receives the data in the network, so as to ensure that each subnet can communicate independently and stably.

![Figure 1. Schematic diagram of multi network coordination technology for broadband carrier scheme](image-url)
4.3. Broadband Carrier Communication can better Support Intelligent Power Consumption and Energy Efficiency Management Services

With the continuous and rapid growth of China's economy, accompanied by the pressure of energy shortage and environmental degradation, the most effective and economic way to face this challenge is to build energy consumption monitoring, management and control system in high energy consumption enterprises, and improve energy use efficiency through technological innovation. According to statistics, 8% of the annual energy loss of industrial enterprises comes from the lack of energy monitoring and maintenance plan. 12% of the energy loss comes from the lack of energy management and control system.

At present, in China, the power consumption and energy consumption are mainly counted by means of manual timing meter reading, which has some problems such as data lag, poor timeliness, single data and so on, so it is unable to grasp the real-time energy consumption data of enterprises in time. PLC scheme provides the possibility for the intelligent energy efficiency management system. Broadband carrier communication technology can provide two-way, real-time, high-speed and secure communication channels in real time, and point-to-point communication can reach 1 Mbps rate. It is much higher than the effective rate (< 5 kbps) provided by narrowband. Micro power wireless transmission speed is high, laboratory test can reach 50 Kbps, but with the rapid attenuation of transmission distance, the field can provide 10 Kbps of effective data when available.

Broadband power line communication can master the power consumption data of each terminal in the current network in real time, accurately and in detail. By collecting the power consumption data of users in different periods, the real-time data is transmitted to the background database for storage and the energy consumption model is established. The distribution network status is counted, analyzed and evaluated from multiple dimensions, and the dynamic curve is adopted in the form of lines and charts, accurate load and network loss information can be obtained, and energy consumption loopholes can be fed back in time, so as to avoid overload of power equipment and deterioration of power quality, and assist managers in dynamically monitoring user load and network loss information. Through the two-way real-time interactive query of abnormal power consumption records of intelligent meters, reliable real-time data is provided for fault analysis, equipment or system with high energy consumption or unreasonable operation is found, suggestions for improving energy-saving operation management are given, more accurate load forecasting is formulated, energy optimization scheduling is guided, energy configuration optimization and three-phase power balance are realized.

With the video monitoring solution, even in key nodes, it can support the transmission of video monitoring data.

4.4. Broadband Carrier Communication can Effectively Improve Power Service Quality and Customer Satisfaction

The most basic requirement of power customers for power supply enterprises is to provide reliable and stable power supply and high-quality service level. It is not only expected that the power supply equipment is harmless to human body and environment, but also that the personal safety and property safety of customers can be guaranteed in the process of power supply. Therefore, the stability and safety of power supply quality is the most important factor of customer satisfaction.

At present, the narrow-band carrier and micro power wireless acquisition scheme adopted in the power consumption information acquisition system shows a low success rate of charge control, which makes the stability and security of power supply not guaranteed. Therefore, the user complaints caused by the untimely payment and power outage of users directly make the image of power supply enterprises in the minds of power customers greatly reduced.

Broadband carrier communication technology provides two-way, real-time and high-speed communication based on power line. The technical comparison of broadband power line carrier and narrowband power line carrier are shown in Table 2. Broadband carrier communication technology effectively solves the problem of low real-time communication in other technical solutions, improves the timeliness of reading customer's electricity information and the accuracy of meter reading, in addition, the sensitivity of control instruction execution has been greatly improved.
Table 2. The technical comparison of broadband and narrowband power line carrier

| Item                    | Narrowband       | Broadband        | Remarks               |
|-------------------------|------------------|------------------|-----------------------|
| Communication rate      | <5KBps           | >2MBps           |                       |
| Working frequency       | Single frequency | 2M-12M           |                       |
| Modulation mode         | FSK/BPSK         | OFDM             |                       |
| Rotation time           | 2-5 hours        | 3 minutes        | Scale of 300 meters   |
| Automatic networking    | 3 hours          | <15 minutes      | Scale of 300 meters   |
| Communication distance  | 500-1000m        | >700m            | Point to point        |

5. Conclusion
This paper analyzes and compares the mainstream communication technologies of the current power consumption information acquisition system, discusses the advantages and disadvantages of various communication technologies, and discusses and analyzes the application prospect of broadband power line carrier communication technology. Compared with other communication technologies, broadband carrier communication technology has obvious advantages in transmission rate, control command issuing and other aspects. In practice, it still needs to be continuously updated and improved, so as to establish a high-speed, two-way, real-time, integrated power consumption information acquisition system, laying a solid foundation for building a unified and strong smart grid in China.

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