Application and Test Research of High-speed Broadband Carrier Communication Technology in Power Information Collection Interconnection System

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Keywords: Broadband carrier, Smart grid, Electricity information.

Abstract. The electricity information collection system plays an important role in improving the energy structure of the grid and improving the utilization efficiency. With the development of power consumption business, broadband technology has become an important part of the communication network of power information system, which is of great significance to support the construction of smart grid. In this paper, the application of high-speed broadband carrier communication in the use of electricity information collection and interconnection system is studied. In view of the problems frequently occurring in the electricity information collection system, it is proposed that information islands are easy to appear in the Data district, and the line loss management is weak. The power information system solution in the case. Through the introduction of system communication performance, consistency and interoperability and other test programs, testing at each operation site, and achieved good results.

Introduction

The power line carrier uses the power line as the communication medium for data transmission, modulates the information data to be transmitted on the low frequency or high frequency carrier signal suitable for power line medium transmission, and transmits along the power line, and the receiving end recovers the original information data by demodulating the carrier signal. The electricity information collection system is an important part of the smart grid construction. It is the basic platform and core support for realizing the intelligent power service system of real-time and flexible interaction between power grid and users. It is also a comprehensive implementation to adapt to the user's ladder price. Technical means to ensure safe and reliable use of electricity in society [1-3]. In order to achieve timely data acquisition, convenient and efficient management, this paper analyzes and tests the data acquisition scheme based on broadband communication technology of intermediate frequency power line, which provides a reliable communication technology choice for improving the real-time performance of the system and expanding the marketing service means of power enterprises.

Power Line Carrier Communication

Power line carrier communication principle. Power line carrier communication [4] refers to a communication method in which information or data is transmitted using a power cable as a medium. Power line carrier communication According to the principle of frequency shifting and frequency division, the original signal is modulated by the carrier, moved to different transmission frequency bands, and then coupled to the power line for transmission through a coupling device with a wave blocker. When transmitting data on the transmitting end, the data to be transmitted is first modulated onto a high frequency carrier of a certain frequency, and then the signal power is amplified and
coupled to the power line. At the receiving end, the useful signal is extracted by a coupling device with a wave blocker, the high frequency signal is separated by the receiver, the interference is filtered out, and finally modulated into a voice or data signal. In power line carrier communication, relay technology is sometimes used to extend the effective communication distance.

**Power line channel characteristics analysis.** Power lines are designed to transmit power rather than to transmit communication data, and their physical characteristics are different from conventional communication transmission media. According to different noise sources, the noise on the low-voltage power line is usually divided into five categories: colored background noise, narrow-band noise, periodic impulse noise asynchronous to power frequency, periodic impulse noise synchronized with power frequency, and random impulse noise. The noise of the low-voltage grid generally decreases with increasing frequency. The noise intensity of the high-frequency band is much smaller than the noise level of the low-band, and the noise characteristics are composed of relatively flat noise and narrow-band interference. Due to the complexity of the structure of the low-voltage distribution network and the diversity and time-varying of the load, the high-frequency signal will inevitably generate a large attenuation when transmitted on the low-voltage power line. The signal attenuation on the power line will increase with the frequency increase. At these frequencies, the attenuation curve will have local peaks; as the transmission distance increases, the attenuation amplitude will increase rapidly; the heavier the load, the greater the overall attenuation of the signal.

M. Zimmermann and K. Dostert proposed the power line multipath channel model in 1999. The research method and transmission model are generally accepted in the research of power line network channel model. Its frequency response $H(f)$ is:

$$H(f) = \sum_{i=0}^{N} g_i(f) e^{-j\alpha_i f} e^{-j2\pi f t_i}$$

(1)

**Network topology [5].** In the broadband carrier communication network, three device roles, CCO, PCO, and STA are defined. The CCO is responsible for completing the functions of networking control, network maintenance management, etc., and its corresponding device entity is the concentrator local communication unit. The STA is a communication unit device role installed in the energy meter and the collector. The STA needs to implement both PCO and STA role functions. The broadband carrier communication network generally forms a multi-level tree network with CCO as the center and PCO as the relay agent to connect all STAs. As shown in Figure 1, it is the topology of a typical broadband carrier communication network.

![Figure 1. Broadband carrier communication network topology.](image)

**Local Communication Coverage Solution**

**Solution model.** Applying the above technologies, according to Figure 2 is the local communication coverage solution. The main station layer is composed of a database server, an application server, a pre-server, a workstation, a firewall, and related network devices, and mainly performs functions such as service application, data collection, control execution, pre-communication scheduling, and database management. The telecommunication channel layer is used for data communication between
the system main station and the collection terminal, including a fiber private network, a wireless private network, and a wireless public network. The collection terminal layer mainly completes local data collection, including on-site collection terminals and metering devices, such as concentrators, collectors, and smart energy meters.

![Figure 2. Power line broadband communication test topology.](image)

**Hardware design.** The concentrator communication unit [6] mainly completes communication between the concentrator and the broadband carrier electric meter or the broadband carrier collector. The SG5000 chip is the first power line broadband carrier communication chip with independent intellectual property rights in China, mainly for power remote meter reading and smart home applications. The SG5000 is applied to the concentrator. It is mainly composed of DSP subsystem, MAC and PHY based on OFDM communication, analog front end and other functional parts. It also integrates peripheral interfaces such as SPI, UART, GPIO and Ethernet MAC. The block diagram of the SG5000-based concentrator communication unit is shown in Figure 3.

![Figure 3. Block diagram of concentrator communication unit based on SG5000.](image)

The broadband carrier meter communication unit mainly completes communication between the broadband meter and the concentrator. SG3000 chip is a high-performance power line broadband communication chip, used for collector, repeater and meter side. It is mainly composed of DSP subsystem [7], MAC and PHY based on OFDM [8] communication, analog front end, etc., and integrates SPI, UART, Peripheral interface such as GPIO. The block diagram of the SG3000-based meter communication unit is shown in Figure 4.

![Figure 4. Principle block diagram of carrier wave communication unit of smart meter based on SG3000.](image)
Broadband Carrier Interconnection Test Solution

Communication performance test. On the basis of normal communication of the tested communication unit, specific noise is introduced through the noise source to evaluate the anti-noise capability of the carrier transceiver module for the established noise to simulate the actual working environment of the communication unit. The system provides Gaussian white noise, impulse noise and narrowband noise to evaluate the noise immunity of the tested communication unit under different noise effects.

Interoperability performance test plan. A multi-level network topology is built to simulate the communication unit field environment, and the communication unit of the carrier communication unit physical layer and the data link layer is collected and analyzed to evaluate whether the communication unit complies with the interconnection standard. At the same time, the communication unit business function is combined to test the network, so as to obtain the networking efficiency of the communication unit under different networking topologies, and test the service application effect of the communication unit by constructing a certain network scale and adding specific network interference.

Mainly have the following functions:
1. The effect of analog RF path attenuation on a wideband carrier communication link;
2. The impact of analog noise [9] (including white noise, narrowband noise, impulse noise, etc.) on the broadband carrier communication link;
3. Data analysis to achieve acquisition and analysis of physical layer communication data frames [10] of the broadband carrier communication link;

Test conclusion

Test topology. In order to verify the application performance of power line broadband communication in the power information collection system, a test environment of two broadband carrier concentrators + 200 broadband carrier meter nodes was built in the power grid communication application technology laboratory of State Grid Corporation. The system is in 200 nodes. The performance of copying time, copying success rate, single-point network access time, multi-zone crosstalk, and network-wide upgrade were tested.

The single-channel meter reading time test mainly evaluates the time required to complete the meter reading of a single station after the equipment is installed and the power line communication network is stabilized.

The test results are shown in Table 1.

<table>
<thead>
<tr>
<th>Rounds</th>
<th>Network size</th>
<th>Round copy method (by electricity meter, copying data by data)</th>
<th>Concurrency method (simultaneously copying 5 electric meters, 3 data volumes combined with copying)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total meter reading time</td>
<td>Average time spent on each data volume</td>
<td>Success rate</td>
</tr>
<tr>
<td>1</td>
<td>200</td>
<td>445s</td>
<td>0.742 s</td>
</tr>
<tr>
<td>2</td>
<td>200</td>
<td>449s</td>
<td>0.748 s</td>
</tr>
<tr>
<td>3</td>
<td>200</td>
<td>459s</td>
<td>0.765 s</td>
</tr>
<tr>
<td>Average value</td>
<td>451s</td>
<td>0.752 s</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 1. Single-table meter reading time test results.
It can be seen from the above test results that the average copying time of each data item in the power line broadband communication mode is only 0.752 seconds, compared with the existing 2 seconds required for the average round-trip power line communication mode (through the same The environmental comparison test found that the limited space is not detailed in this article), the acquisition rate increased by more than 1.5 times. If, under the same hardware conditions, the software implementation adopts the method of concurrent multi-frame, the average time of each data volume is only 0.096 seconds, which is more than 6 times higher than that of the existing broadband. The 2-second acquisition rate required for round-tripping is narrowed by nearly 20 times compared to narrow-band power line communication.

Summary

The construction and application of the electricity information collection system requires real-time and reliable communication technology as a support. According to the communication bandwidth characteristics of high-speed power line broadband carrier communication, this paper proposes a method of simultaneous meter reading and multi-frame simultaneous transmission through multiple nodes to effectively improve the meter reading speed. It can be effectively improved in the laboratory environment test. More than one. It is based on the existing statute to expand and effectively improve the speed of meter reading, and can play a good role in enhancing the real-time performance of power consumption information without increasing the hardware investment. The rational and effective use of high-speed power line broadband carrier communication technology will greatly improve the real-time and interactive channel of the current power information collection system. High-speed power line broadband carrier communication technology, because of its high communication rate, strong real-time performance and high reliability, not only meets the construction and application requirements of current power consumption information collection systems, but also provides technical support for the two-way interaction of smart grids in the future. The expansion of marketing service means provides a strong guarantee.

References


