Research on Influence of Power Carrier Communication on Smart Energy Meter

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Abstract. In order to enable the smart energy meter to conduct trade settlement work in a normal and stable manner, in order to ensure the interests of both power users and power companies, the impact of power carrier communication on smart energy meters is studied. Through the carrier communication impact test of various bandwidth, frequency and intensity, it analyzes whether it has influence on the metering function, timing function, storage function and carrier communication function of the intelligent electric energy meter. The test analysis of the system provides data support for the in-depth study of the energy meter detection method and the operating environment.

1. Introduction

With the continuous development of China’s smart grid, users’ requirements for smart grids continue to increase. The remote meter reading system in the smart grid can liberate a large amount of manpower, save costs, and greatly improve the level of intelligence and automation of the grid. In the implementation of various remote meter reading, low-voltage power line carrier communication technology shows a unique advantage. The transmission medium is a currently existing power line network, and the carrier signal is superimposed on the power line to transmit data. It not only allows the communication network to cover every corner, but also makes full use of the existing low-voltage distribution network, which saves the cost of channel laying and has a very broad application prospect.

At present, the smart energy meter with carrier communication function has been greatly promoted by the State Grid Corporation. However, the relevant technical standards only stipulate qualitatively that the smart energy meter can be correctly measured under the carrier communication state, and does not affect the data stored in the table. The specific experimental method and reasonable error range of the influence of carrier communication on the measurement error of smart energy meter are not explicitly stated. At present, the research work in the field of carrier communication mainly includes: research on the principle of power line carrier communication, research and modeling of power line carrier communication channel characteristics, research and improvement of power line carrier communication technology protocol, establishment of relevant standards for power line carrier communication technology, power line Application of carrier communication.

2. Intelligent electric energy meter carrier communication measurement error influence detection system

In order to verify the influence of the energy meter carrier communication on the metering error of the energy meter, the test scheme of the intelligent power meter carrier communication measurement error detection system is shown in Figure 1. According to the system diagram, the whole system consists of standard power source, carrier attenuator, and carrier concentrator and carrier energy meter.
The standard power source mainly provides standard power signals for the system and the meter to be tested, and compares the errors. The power standard source is a type of voltage and current signal generating device. The standard power source independently adjusts the voltage, the magnitude of the current, and the phase difference between the two. The standard power source also includes a standard meter that can accurately measure the voltage, current, frequency, and voltage and current combined with the virtual power. The standard table value is used as a comparison reference standard to realize various measuring devices/systems with variable frequency power as the main measurement object. Calibration and verification. The carrier attenuator mainly isolates the high frequency carrier signal of the electric energy meter and the carrier concentrator from the power source, and avoids the influence of the carrier signal on the standard table. The carrier concentrator mainly reads the electric energy meter and simulates the on-site reading environment with the carrier electric energy meter. The carrier concentrator is a key device in the low-voltage power line carrier centralized meter reading system. The carrier energy meter is used as a post meter to be used as the meter to be measured.

3. Research on Influence of Narrowband Carrier Communication on Measurement Error of Electric Energy Meter

Three-phase four-wire smart energy meter from three different manufacturers was used to perform experiments using the frequency points used by the carrier module. The sampling frequency of the measuring chip used by the manufacturer's one energy meter is 3.125 kHz; the sampling frequency of the measuring chip used by the manufacturer's two smart energy meter is 8 kHz; the sampling frequency of the measuring chip used by the manufacturer's three smart energy meter is 3.2 kHz.

In the vicinity of the carrier frequency point used by the three carrier module manufacturers, according to the theoretical analysis of the influence of carrier communication on the measurement accuracy of the smart energy meter, combined with the sampling frequency of different metering chips, the carrier capable of forming a 50 Hz frequency signal after sampling by different metering chips is calculated. The frequency is used to generate the theoretically most influential carrier signal by an arbitrary signal generator. The carrier signal is coupled to the carrier input interface of the carrier isolation attenuation device via the power amplifier. Each three-phase smart energy meter tests six frequency points, including three currently used frequency points and three nearby theoretically most influential frequency points. The experimental plan frequency points are shown in Table 1.
### Table 1. Experimental plan carrier frequency point.

| Manufacturer | Frequency point 1 | Frequency point 2 | Frequency point 3 | Frequency point 4 | Frequency point 5 | Frequency point 6 |
|--------------|------------------|------------------|------------------|------------------|------------------|------------------|
| 1            | 132kHz           | 131.30kHz        | 270kHz           | 268.80kHz        | 421kHz           | 418.80kHz        |
| 2            | 132kHz           | 128.05kHz        | 270kHz           | 271.95kHz        | 421kHz           | 423.95kHz        |
| 3            | 132kHz           | 131.25kHz        | 270kHz           | 268.85kHz        | 421kHz           | 422.45kHz        |

In the experiment, three kinds of carrier intelligent electric energy meters are used, and the change of the average value of the error of the measured table in the case of no loading wave and loading wave is measured at the planned frequency point specified in Table 1, and the case where the wave is not loaded is recorded. When 10 carriers are added in the case of carrier, the average value is calculated. Compare the changes of the mean value of the error before and after the loading wave, analyze and give the conclusion.

The first set of experiments is the experimental measurement data of a manufacturer's three-phase smart energy meter. In the experiment, the three-phase voltage source is 220V, and the three-phase current source is 1A. The error data measured in the experiment is shown in Table 2.

### Table 2. Manufacturer one three-phase test data.

| Power factor | 132kHz | 131.30kHz | 270kHz | 268.80kHz | 421kHz | 418.80kHz |
|--------------|--------|-----------|--------|-----------|--------|-----------|
| 1.0          | 0.0081 | 0.0282    | 0.0062 | 0.0093    | 0.0012 | 0.0031    |
| 0.5L         | 0.0072 | 0.0260    | 0.0056 | 0.0052    | 0.0028 | 0.0018    |
| 0.8C         | 0.0085 | 0.0192    | 0.0052 | 0.0072    | 0.0031 | 0.0020    |

It can be seen from the above experimental data that when the carrier frequency is 132 kHz, the measurement error caused by carrier communication is about 0.008%. At 131.30 kHz, the measurement error caused by carrier communication is close to 0.03%, which is significantly larger than that at 132 kHz. At a carrier frequency of 270 kHz, the measurement error caused by carrier communication is about 0.005%. At 268.80 kHz, the error is close to 0.01%. However, at a higher frequency of 421 kHz, the error caused by carrier communication is significantly reduced, and the maximum does not exceed 0.003 %, and at 418.80 kHz, the error increase is not significant.

The second set of experiments is the experimental measurement data of the manufacturer's two-phase three-phase smart energy meter. In the experiment, the three-phase voltage source is 220V, and the three-phase current source is 1A. The error data measured in the experiment is shown in Table 3.

### Table 3. Manufacturer two three-phase test data.

| Power factor | 132kHz | 128.05kHz | 270kHz | 271.95kHz | 421kHz | 423.95kHz |
|--------------|--------|-----------|--------|-----------|--------|-----------|
| 1.0          | 0.0067 | 0.0095    | 0.0069 | 0.0093    | 0.0010 | 0.0031    |
| 0.5L         | 0.0076 | 0.0100    | 0.0055 | 0.0094    | 0.0023 | 0.0033    |
| 0.8C         | 0.0087 | 0.0082    | 0.0049 | 0.0132    | 0.0029 | 0.0050    |

It can be seen from the above experimental data that when the carrier frequency is 132 kHz, the measurement error caused by carrier communication is about 0.007%. At 128.05 kHz, the measurement error caused by carrier communication is close to 0.01%, which is significantly larger than that at 132 kHz. At a carrier frequency of 270 kHz, the measurement error caused by carrier communication is about 0.006%. At 271.95 kHz, the error is close to 0.01%. However, at 421 kHz with higher frequency,
the error caused by carrier communication is significantly reduced, and the maximum is 0.002%. Left and right, and at 423.95 kHz, the error increase is not obvious, about 0.003%.

The third group of experiments is the experimental measurement data of the manufacturer's three-phase smart energy meter. In the experiment, the three-phase voltage source is 220V, and the three-phase current source is 1A. The error data measured in the experiment is shown in Table 4.

### Table 4. Manufacturer three-phase test data.

| Power factor | 132kHz | 131.25kHz | 270kHz | 268.85kHz | 421kHz | 422.45kHz |
|--------------|--------|-----------|--------|-----------|--------|-----------|
| 1.0          | 0.0065 | 0.0134    | 0.0057 | 0.0086    | 0.0019 | 0.0031    |
| 0.5L         | 0.0066 | 0.0117    | 0.0064 | 0.0065    | 0.0021 | 0.0023    |
| 0.8C         | 0.0063 | 0.0089    | 0.0065 | 0.0032    | 0.0020 | 0.0019    |

It can be seen from the above experimental data that the measurement error caused by carrier communication is about 0.006% at a carrier frequency of 132 kHz. At 131.25 kHz, the measurement error caused by carrier communication is above 0.01%, which is significantly higher than that at 132 kHz. At the carrier frequency of 270 kHz, the measurement error caused by carrier communication is about 0.006%, and the measurement error caused by each power factor download wave communication increases when the carrier frequency is 268.8 kHz; however, the carrier frequency is 421 kHz and nearby. At 422.45 kHz, the carrier communication causes the measurement error to be below 0.002%.

It can be seen from the analysis of the above three sets of experimental data that the measurement error caused by carrier communication is obvious at 132 kHz and 270 kHz with relatively low carrier frequency, and the theoretically most affected frequency point near these two frequencies, the error significantly larger than 132 kHz and 270 kHz, the amplitude can reach an order of magnitude, but does not exceed the error level range of the smart energy meter.

### 4. Research on Influence of Broadband Carrier Communication on Measurement Error of Electric Energy Meter

The three-phase four-wire smart energy meter of three different manufacturers is also used, and the frequency points used by the carrier module are respectively tested. Each three-phase smart energy meter tests six frequency points, including three currently used frequency points and three nearby theoretically most influential frequency points. The experimental plan frequency points are shown in Table 5.

### Table 5. Experimental plan carrier frequency point.

| Manufacturer 1 | Frequency point 1 | Frequency point 2 | Frequency point 3 | Frequency point 4 | Frequency point 5 | Frequency point 6 |
|----------------|------------------|------------------|------------------|------------------|------------------|------------------|
|                | 2MHz             | 1.98MHz          | 5MHz             | 4.92MHz          | 8MHz             | 7.98MHz          |

| Manufacturer 2 | Frequency point 1 | Frequency point 2 | Frequency point 3 | Frequency point 4 | Frequency point 5 | Frequency point 6 |
|----------------|------------------|------------------|------------------|------------------|------------------|------------------|
|                | 2MHz             | 1.96MHz          | 5MHz             | 5.04MHz          | 8MHz             | 8.09MHz          |

| Manufacturer 3 | Frequency point 1 | Frequency point 2 | Frequency point 3 | Frequency point 4 | Frequency point 5 | Frequency point 6 |
|----------------|------------------|------------------|------------------|------------------|------------------|------------------|
|                | 2MHz             | 1.97MHz          | 5MHz             | 4.93MHz          | 8MHz             | 8.02MHz          |

The first set of experiments is the experimental measurement data of a manufacturer's three-phase smart energy meter. The error data measured in the experiment is shown in Table 6.
It can be seen from the above experimental data that when the carrier frequency is 2MHz, the measurement error caused by carrier communication is about 0.007%. At 1.98MHz, the measurement error caused by carrier communication is close to 0.02%, which is significantly larger than that at 2MHz. At 5MHz carrier frequency, the measurement error caused by carrier communication is about 0.004%, and the error is close to 0.007% at 4.92MHz. However, at 8MHz with higher frequency, the error caused by carrier communication is significantly reduced, the maximum is less than 0.002%, and at 7.98MHz, the error increase is not obvious.

The second set of experiments is the experimental measurement data of the manufacturer's two-phase three-phase smart energy meter. The error data measured in the experiment is shown in Table 7.

| Power factor | 2MHz | 1.96MHz | 5MHz | 5.04MHz | 8MHz | 8.09MHz |
|--------------|------|---------|------|---------|------|---------|
| 1.0          | 0.0057 | 0.0085 | 0.0056 | 0.0083 | 0.0010 | 0.0021  |
| 0.5L         | 0.0066 | 0.0090 | 0.0049 | 0.0084 | 0.0013 | 0.0023  |
| 0.8C         | 0.0067 | 0.0080 | 0.0045 | 0.0097 | 0.0016 | 0.0026  |

It can be seen from the above experimental data that when the carrier frequency is 2MHz, the measurement error caused by carrier communication is about 0.006%. At 1.96MHz, the measurement error caused by carrier communication is close to 0.009%; at carrier frequency 5MHz, carrier communication the measurement error is about 0.005%. At 5.04MHz, the error is close to 0.009%. However, at 8MHz with higher frequency, the error caused by carrier communication is significantly reduced, the maximum is about 0.001%, and the error is 8.09MHz. The increase is not obvious, at around 0.002%.

The third group of experiments is the experimental measurement data of the manufacturer's three-phase smart energy meter. The error data measured in the experiment is shown in Table 8.

| Power factor | 2MHz | 1.97MHz | 5MHz | 4.93MHz | 8MHz | 8.02MHz |
|--------------|------|---------|------|---------|------|---------|
| 1.0          | 0.0055 | 0.0094 | 0.0047 | 0.0076 | 0.0009 | 0.0009  |
| 0.5L         | 0.0056 | 0.0097 | 0.0054 | 0.0055 | 0.0009 | 0.0009  |
| 0.8C         | 0.0053 | 0.0099 | 0.0044 | 0.0052 | 0.0008 | 0.0009  |

It can be seen from the above experimental data that the measurement error caused by carrier communication is about 0.005% at the carrier frequency of 2MHz, and the measurement error caused by carrier communication is above 0.009% at 1.97MHz; at 5MHz at carrier frequency, the carrier The measurement error caused by communication is about 0.004%, and the measurement error caused by each power factor download wave communication increases when the carrier frequency is 4.93MHz. However, when the carrier frequency is 8MHz and the nearby 8.02MHz, the carrier communication causes measurement. The error is below 0.001%.

It can be seen from the analysis of the above three sets of experimental data that the measurement error caused by carrier communication is obvious when the carrier frequency is relatively low at 2 MHz and 5 MHz, but it does not exceed the error level range of the smart energy meter.
5. Conclusion

Power carrier communication is a communication technology that uses power lines for data transmission, that is, using the existing power grid as a transmission medium for signals, so that the power grid can transmit data while transmitting power. According to the different frequency bands used, low-voltage power line carrier communication is generally divided into narrow-band power line carrier communication (10 kHz to 500 kHz) and broadband power line carrier communication (2 MHz to 20 MHz). The difference between narrow-band and broadband in the application effect is generally concentrated in the communication rate. Noise interference, communication distance difference and so on. The experimental comparison can verify that the effect of the wideband carrier is smaller than that of the narrowband carrier.

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