Study on the test method of rapid change of load current of intelligent electricity meters

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Abstract: With the continuous changes of the working environment of the electric energy meter, the dynamic detection method of the electric energy meter becomes more and more important. Therefore, in recent years, the IEC 62052-11 Standards Committee has proposed to add a rapid change test of electric energy meter load current. This article proposes an effective dynamic test method according to the requirements of this regulation standard, builds an electric energy meter dynamic error test platform and develops a software test system. An anti-submarine mechanism is proposed for the electric energy measurement algorithm of the smart meter, and the load current rapid change test of various electric energy meters from different manufacturers at home and abroad is tested, and the correctness of this test method is verified.

1. Introduction

With the rapid development of smart grids, the types of loads in the power system have become more abundant[1]. There are not only a large number of steady-state loads, but also new energy sources and dynamic unsteady-state loads[2]. Such dynamic loads will show more and more trend.

The accuracy of electricity meters is normally defined and verified only for stationary conditions. However, in practical situation the load current can vary frequently with high amplitude[3]. Examples are temperature regulated heaters, air conditioners, arc welding systems etc. This leads to a large number of harmonics and interharmonics in the grid signal, some instrument designs show obvious accuracy error in this case[4]. This will directly affect the accuracy of energy metering, so for the electricity meters with this need, the dynamic performance requirements will be put forward[5].

Some meters designs have exhibited significant accuracy errors under such condition, mainly due to incorrectly implemented current range gain switch algorithms[6]. This test is intended to verify accuracy under varying load condition using different duty cycles. AS the load switching and the meter internal gain switching are not synchronized, the accuracy error may vary over time depending on how the load switch transients are timed with respect to gain switching[7-8]. If the test time is sufficiently long, in this case 4 hours, the timing conditions will vary similarly to practical situations and accuracy problem can be revealed.

2. The test method

In recent years, The IEC 62052-11 standards board recommended that electric energy meters should
be added fast load current variations test, the intent of this test is to ensure that the accuracy of the meter is not susceptible to fast load current variations.

The test shall be carried out under the condition specified in:

a) Voltage circuits and auxiliary power circuits energized with their highest specified nominal voltages;

b) For a.c. meters, the power factor shall be according to the values given in the relevant particular requirement (accuracy class) standards;

The test shall be applied to the mains port of directly connected meters and to the current transformer port of transformer operated meters:

c) The test current shall repeatedly be switched between on and off states;

d) During the toff period, the value of the test current shall be as given in the relevant particular requirements (accuracy class) standards;

e) During the toff period, the value of the test current shall be zero;

f) The duration of the ton and toff periods shall be according to the following test profiles:

1) ton = 10 s, toff = 10 s, total test duration 4 hours;
2) ton = 5 s, toff = 5 s, total test duration 4 hours;
3) ton = 5 s, toff = 0.5 s, total test duration 4 hours;

g) For a.c. meters, the turn-off times and the turn-on times need not to be synchronized with the zero crossings of the mains frequency. The switch between on and off states shall occur within one cycle at nominal mains frequency. The tolerance for ton and toff shall be +/- one cycle at nominal mains frequency;

Acceptance criteria: A, applied separately to each test f(1), f(2), f(3); the accuracy shall be verified after each test.

3. Typical equipment quality failure

The dynamic error test system for load current of electric energy meters is composed of three-phase electricity meters verification device (including programmable power supply, standard electricity meters, and master computer), power analyzer, oscilloscope and electricity meters under test. The structure block diagram is shown in figure 1.
The test system uses the master computer to establish the corresponding steady or dynamic load signal mathematical model, through the DA converted analog voltage small signal control power source calibration voltage/current signal output. Controlled power source outputs independent three-phase voltage and current signals to form virtual load. In the dynamic load test model, the voltage signal remains unchanged and the current signal sets the on-off ratio according to the test item, but there is no dynamic change of pulse and frequency.

The error processing module unit collects the power pulse output of the watt-hour meter and the standard watt-hour meter, compares it with the theoretical power or electric energy of the reference load model after the periodic scale conversion, and outputs the error of the watt-hour meter. That is, the dynamic error of the watt-hour meter and the accuracy and effectiveness of measurement are completely dependent on the adaptability of the watt-hour meter to the dynamic signal through comparison with the standard meter. Therefore, the accuracy of the standard meter is worth considering under dynamic conditions. Therefore, the power analyzer is used as a comparison standard in this test system to compare the error characteristics of standard and measured electricity meters.

The comparison standard used in this test system is YOKOGAWA power analyzer WT3000E, which can carry out active power integration (watt-hour). The true effective value of the voltage or current measured during the integral is to square each instantaneous value in a period, average them, and then take the square root. According to the calculation formula of active power, it can be known

\[ P = \frac{1}{T} \int_0^T f(t)^2 \, dt \]

where \( f(t) \) is a function of the input signal, \( T \) represents a cycle of the input signal, \( U_{\text{rms}} \) or \( I_{\text{rms}} = \sqrt{\frac{1}{T} \int_0^T f(t)^2 \, dt} \).

In order to verify the feasibility of the test method, the same power analyzer with different models of standard meters was tested. The test bench body used in the experiment is FLUKE6100A, and the comparison standard meter is YOKOGAWA WT3000E. This experiment uses the method of packing FLUKE6100A electric energy. The power source is set to output 0.88KWh and then stops outputting electric energy. The test data are shown in the table 1 below.

| The time condition | Drop the waveform | FLUKE6100A | The theoretical value | YOKOGAWA WT3000E | error |
|-------------------|------------------|------------|----------------------|------------------|-------|
| \( \text{ton} \) (s) | \( \text{toff} \) (s) | The test of | \( \text{Rising edge} \) | \( \text{Fall time} \) | KWh | KWh | KWh | % |
| 10 | 10 | 14400 | 0.0001s | 9.9998s | 0.4419 | 0.44 | 0.441983 | 0.01 |
| 5 | 5 | 14400 | 0.0001s | 4.9998s | 0.88 | 0.44 | 0.440246 | 0.06 |
| 5 | 0.5 | 14400 | 0.0001s | 0.4998s | 0.88 | 0.800 | 0.800112 | 0.01 |

According to the experimental data, the accumulated power value of YOKOGAWA WT3000E within 4h is not much different from the theoretical true value, and the error is no more than 6/10000. Therefore, it is feasible for this test system to use YOKOGAWA WT3000E as a standard meter.

4. Smart meter measurement algorithm

The filter in the power metering algorithm of electricity meters will cause signal lag, which is similar to step response. Although different chip increase/decrease time, but in the long run, the energy is conserved will not result in the loss of energy, in the processing of creep and the selection of electrical energy accumulated data source, because this test model is the flow of electricity for a period of time,
for a period of time without current, the cause of the current period, metering chip in a creep state. However, the average power/average current is generally used as the starting/potential criterion for the metering chip of electricity meters. The faster the updating rate of the average power is, the stronger the metering chip's ability to respond to the dynamic load model, namely, the smaller the accuracy change is. The power waveform of the intelligent electricity meters is shown in the figure 2 below.

Figure 2. Power waveform of smart electric energy meter measurement algorithm

The anti-submersion or starting of the metering chip of the intelligent electricity meter is determined according to the average power/average current, which leads to the lag problem. When the moment of T-1~T0, Pave=0<Pstart, then it is determined that T0/T1 is in the creeping state. The instantaneous power of T0/T1 is discarded and not counted as energy. When T1~T8, Pave>Pstart, then the instantaneous power of T2~T9 is normally included in the electric energy. When T9/T10~T0(next cycle), Pave<Pstart, there is also a loss of energy. Therefore, if the current interruption time is long, there will be a large error.

Through research and analysis, the submersion algorithm and the energy accumulation data source are improved, and the average power is used as the submersion criterion, and the power value is used as the energy accumulation data source to modify the anti-submersion mechanism. Prevent latent power compare value Pave hawks choose average power quickly, based on the rapid average power energy accumulation Pave hawks, rather than the instantaneous power, can avoid the lag problem, because the average value using rapid accumulation, also as far as possible reduce lag pulse, as a result of rapid average power value is hidden, Increased runout reduces the reliability of anti-submarine. When T0,Pave=0<Pstart, then it is determined that T0 is in the state of submersion, the average power of T-1 is discarded and not counted in the energy. When T1~T8,Pave>Pstart, then the instantaneous power of T0~T7 (average power T1~T8) is normally included into the electric energy. When T9/T10~T0(the next cycle) , Pave<Pstart, there is energy loss (T8~T10). Under the short-term load model, only energy is lost at time T0, and the impact on the measurement error is negligible. Therefore, the errors in both the new and old algorithms are qualified. Under the long-term load model, the old algorithm uses the average power as the anti-submarine, and the energy at T0 will be lost, causing amplitude errors.

5. Analysis of results
Based on the establishment of a test platform for rapid changes in load current of electric energy meters (as shown in figure 3 below), this paper develops a corresponding software test system. For the line electric energy meter, when the power factor is 1.0, dynamic tests under different modes are carried out.

The test bench body adopts German EMH 67104, the comparison standard meter is MTERS600.3, the oscilloscope model is YOKOGAWA DL850EV, and the standard meter adopts YOKOGAWA WT3000E. The test object and the model required by the standard are 3×57.7/100V, 1.5 (6) A
three-phase meters, its corresponding turning current is 0.25A, the accuracy is 0.5S level, and the corresponding is C. The load current rapid change test was carried out. Through the analysis of the output waveform of the EMH source, it can be seen that the voltage and current waveforms tend to be stable after about 3s after the output source is started (as shown in figure 4 below), and the current has a smaller amplitude rebound when the current is started or cut off. Therefore, the output source is increased by \( T_{t^*} = 60s \) before the test, the purpose is to reduce the influence of the source start time on the error.

For each dynamic test of the electric energy meter, the test results are shown in table 2, under the same on-off ratio in the long-term dynamic load mode, the dynamic error of the tested NO.3 and the tested NO.4 changes greatly. The dynamic errors of NO.1 and NO.2 in the long-term dynamic load mode are both less than 0.1%. The electric energy meter can perform electric energy measurement well and is suitable for dynamic error test. Therefore, it can be known from the test results that the method of improving the creeping algorithm and the energy accumulation data source for the smart energy meter is reliable.
| Time (s) | Average power of standard meter NO. 1 | Standard meter NO. 2 | Error | NO. 3 | Error | NO. 4 | Error |
|---------|--------------------------------------|----------------------|--------|--------|--------|--------|--------|
| 60      | 130.331 Wh | 523.497 Wh | 523.3 | -0.01 Wh | 523.4 | -0.01 Wh | 516.32 Wh | 1.37% |
| 60      | 130.082 Wh | 523.404 Wh | 523.2 | -0.03 Wh | 523.3 | -0.02 Wh | 516.24 Wh | 1.36% |
| 60      | 236.057 Wh | 948.514 Wh | 947.9 | -0.06 Wh | 948.1 | -0.04 Wh | 939.43 Wh | -0.96% |

6. Conclusion

Based on the principle of smart electric energy meter measurement, this paper proposes a test method for rapid change of load current of electric energy meter and an anti-submarine mechanism of smart electric energy meter, builds a test platform for rapid change of load current of intelligent electric energy meter, and develops a corresponding software test system. The selection of the standard meter is carried out in this way, and the power analyzer is used as a standard electric energy meter for the first test. The test results show that the error of the electric energy meter with anti-submarine mechanism meets the requirements, and the test method and platform can meet the test item of the electric energy meter, which provides a guiding direction for the comprehensive development of the subsequent electric energy meter.

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