Common fault Analysis and Countermeasures of key Components of intelligent electricity meter

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Abstract: In recent years, with the State Grid Corporation's vigorous construction of smart grids, smart meters have been rapidly promoted in the power system. After several years of online operation, the operating reliability of smart meters has also stabilized. However, in the process of widespread use of smart electric energy meters, the quality problems of clock chips, batteries and other components have also been exposed. This article takes the component failures encountered in the detection and operation of the smart electric energy meter as an example, analyzes the causes of the failures based on the four typical abnormal phenomena, and then conducts the opening detection for the above reasons and determines the nature of the failure based on the test conclusions. Finally, a corresponding fault management platform is established through the collection of electric energy meter fault data, which realizes all-round management and control of the fault handling process and selection of the qualifications of smart meter suppliers, thereby ensuring the quality of components and improving the operation of smart electric meters reliability.

1. Introduction
As one of the basic equipment of power grid data acquisition, smart electricity meter has played an important role in the construction of smart power grid since it was popularized and applied in 2009[1]. As of Hundreds of millions of smart meters have been installed nationwide[2]. The relevant technical specifications require the life of single-phase and three-phase smart electricity meters to be no less than 10 years[3-4]. At present, it has come to the rotation period of intelligent electricity meters, and relevant researches on the reliability of intelligent electricity meters are also being carried out in succession[5]. Due to the comprehensive and intelligent functions of intelligent electricity meters, their quality of operation has attracted more and more attention from customers, power companies and the society[6]. According to the regulations of the State Grid Corporation, intelligent electricity meters shall be tested by the State Grid Metering Center and the Provincial Metering Center before installation and operation, and shall not be produced and supplied in batches until a qualified test report is issued[7].

This article takes the typical failures encountered during the full performance test of the smart energy meter before delivery and after installation and operation as an example. First, the typical failure phenomenon of the smart energy meter is preliminarily inferred to cause the failure, and then the cover is opened for the above reasons and tested according to the test Conclusion. Determine the nature of the fault, and finally establish a fault meter data management platform to control the fault
handling process in an all-round way, and through the implementation of the supplier evaluation system, select high-quality suppliers, and realize the quality control of the smart energy meter components. The source guarantees the quality of smart energy meters.

2. Common typical faults of smart energy meters

Compared with traditional electric energy meters, smart electric energy meters have more functions, complicated process links, and large differences in the on-site operating environment. Maintenance is relatively difficult. Due to the quality of components, manufacturing processes, and software defects, some electric energy meters are in testing and application. During the process, several quality problems will gradually be exposed [8], such as battery undervoltage, black screen of electric energy meter, communication failure, etc. from time to time. These problems not only affect the safety of grid operation, but also affect the power users’ Satisfaction and trust. The Provincial Metrology Center is mainly responsible for carrying out tests on the adaptability of electric energy meters before production, sample comparison before supply, and software comparison tests. The specifications of smart electric energy meters are checked strictly in accordance with the technical requirements and test items in [3] and [4]. Based on the summary of the laboratory test data and the fault phenomena of the smart electric energy meter running on site in recent years, according to the cause of the fault, the faults of the smart electric energy meter are divided into four types: work quality, external factors, force majeure, and equipment quality failures. The type of failure cases are shown in figure 1. It can be seen from figure 1 that equipment quality failure is an important factor affecting the quality of electric energy meters. The following four typical cases of equipment quality failures of smart electric energy meters are introduced in detail.

![Proportion figure of all kinds of fault cases](image)

3. Typical equipment quality failure

3.1. Stop copying battery under voltage

Smart energy meters have functions such as energy measurement, data storage, freezing, etc. At the same time, in order to facilitate the employees of the power supply company and customers to view the data in the meter when the electricity meter is out of power, it must also meet the power outage meter reading function, so ensure that the power outage meter reading. The normal operation of the battery is the key to realize this function. The power-off meter reading battery provides power to the meter’s liquid crystal chip when the three-phase smart energy meter is powered off. In order to make
the power-off battery work within the specified life, the quality of the battery and the low power consumption design of the control circuit Technical conditions are very important. After summarizing the failures of smart meters that have been running on site in recent years, it is not difficult to find that the screen cannot be woken up due to the undervoltage of the power reading meter battery.

Battery undervoltage during power failure means that the meter reading battery has no voltage or the voltage is too low, causing the LCD screen to not work normally, resulting in the inability to read the meter. Considering that there are two possibilities for causing early battery failure: one is the capacity of the battery itself, and the other is the unreasonable design of the electric energy meter, which causes high current discharge. A total of 6 qualified and unqualified meters are randomly selected, and the appearance of the undervoltage battery is inspected. It is found that there is no leakage, deformation, dents, etc., and the external positive and negative terminals of the battery are well welded, and there is no false welding, unpleasant sight. Next, measure the battery voltage and power consumption of the meter. After the measurement, it is found that the voltage of qualified and unqualified meters is very different, while the power consumption is very small, both 20-28uA (see table 1 below). The result is normal, so it meets the design requirements.

| Sample NO. | The battery voltage | Meter reading battery current | Note                     |
|------------|---------------------|-------------------------------|--------------------------|
| 1#         | 5.8V                | 27uA                          |                          |
| 2#         | 6.0V                | 24uA                          |                          |
| 3#         | 1.3V                | 24uA                          | Test after battery      |
|            |                     |                               | replacement             |
| 4#         | 5.9V                | 22uA                          |                          |
| 5#         | 1.27V               | 24uA                          | Test after battery      |
|            |                     |                               | replacement             |
| 6#         | 5.76                | 23uA                          |                          |

Take four samples of batteries with normal voltage (1#/2#/4#/6#) for 20mA constant current discharge test at room temperature, and the discharge capacity is about 1050mAh (see figure 2). Judging from the sample capacity, the battery capacity without undervoltage is normal.

![Figure 2. Constant current discharge test curve](image_url)
The undervoltage battery sample (3#) was disassembled and analyzed, and the internal lithium chip in the sample was not completely reacted, as shown in figure 3. The sample (6#) was disassembled and analyzed after the constant discharge test. There are very few internal lithium chips, indicating that the reaction is complete, as shown in figure 4.

The undervoltage battery samples were dissected, and the anatomical phenomena are summarized as follows:

A. The lugs are welded firmly;
B. Take out the winding core, it can be seen that there is no electrolyte overflow in the winding core (see figure 5). Refer to Picture 6 of a qualified electrolyte battery to judge that the electrolyte of the undervoltage battery is insufficient;
C. The diaphragm is covered completely without skew;
D. The pole piece & diaphragm are intact, without damage, perforation and other defects.

According to the above experimental conclusions, it can be seen that the lack of electrolyte is the main reason for the undervoltage of the power-off meter reading battery. After replacing the battery with the black screen electric energy meter, it is found that the LCD screen resumes the normal wake-up function.

3.2. Clock chip fault
Because of its accurate clock unit, the smart electric energy meter can record and store events related to the electricity consumption of electricity customers. At the same time, to support the national "tiered electricity price" policy, it can also measure electricity at multiple rates and periods. At this stage, the implementation of the clock unit of the smart energy meter mainly includes the independent clock chip mode and the SOC (energy meter dedicated chip) mode of the energy meter chip. The former clock chip itself has timing and temperature compensation functional units, and the MCU can read and write data with the clock chip through the IC bus. The latter integrates the clock circuit RTC
(real-time clock), LCD (liquid crystal display) drive module, MCU, etc. on a dedicated chip, and ensures the accuracy of the clock by means of capacitance and digital compensation.

During the detection process, it was found that the time and date displayed by the smart electric energy meter did not match the actual situation, and the time period rate number was not accurate when the electric energy meter was powered on. According to the working principle of the electric energy meter, the MCU of the electric energy meter will periodically obtain the real-time clock of the clock chip. If the clock chip can work normally and the time data is valid, the current time of the meter is updated. After on-site analysis, it is found that the second time displayed by the meter has been cyclically displayed during the period from 35 to 59 (that is, the hour and minute time from second to 59 seconds is not normally rounded, but it starts to cycle from 35 seconds). According to the above phenomenon, it is preliminarily judged to be an electric meter The failure of the internal clock chip is the main reason for the discrepancy between the displayed time and date.

The program operation flow chart of the rate number and time in the schedule is shown in figure 7 below:

![Figure 7. Logic diagram of the program runs](image)

Either one of the above two logical relationships can make the rate function perform rate update action. If there is no time or second rollover action, the rate update flag cannot be set, and the rate function cannot be updated. Through the analysis of the internal clock register of the clock chip and the software design program, it is judged that the cause of the failure is that the value in the clock register is not carried, causing the value in the register to keep circulating, and finally leading to the clock and rate period error.

After the on-site lid opening test, the resistance value of 6 pins (power pins) and 7 pins (ground pins) of the clock chip of the faulty watch is measured to be 13.00MΩ (good chip resistance is infinite), so it is inferred that it is due to the chip The internal short circuit between pin 6 (power pin) and pin 7 (ground pin) causes damage to the internal time register of the chip.

Replace the new clock chip on the faulty energy meter, set the current date and time for the energy meter (standard time is 2019-12-22 11: 10: 55, after the setting is successful, the time in the meter is 2019-12-22 11: 10: 55). Observe and record the time of the electric energy meter for 8 consecutive days, and compare it with the time of the standard clock source (see table 2 below), and conduct a daily timekeeping error test on the next day (see table 3 below), as shown in table 2 and table 3. It can be seen that the electric energy meter works normally.
Table 2. Time comparison table

| Date       | Standard time | Meter time | Standard time | Meter time |
|------------|---------------|------------|---------------|------------|
|            |               | 2019-12-23 | 10:02:06      | 2019-12-23 |
|            |               | 15:32:26   |               | 15:32:26   |
|            |               | 2019-12-25 | 09:53:45      | 2019-12-25 |
|            |               | 08:34:07   |               | 08:34:07   |
|            | 2019-12-29    | 10:32:36   | 16:57:11      | 14:56:47   |
|            | 2019-12-30    | 11:15:33   | 11:15:33      | 14:56:47   |
|            | 2019-12-31    |            | 2020-01-04    |            |
|            | 2020-01-04    |            |               |            |

Table 3. Error test of daily timing

| Date       | Daily timing error (s/d) |
|------------|--------------------------|
| 2019-12-22 | 0.00                     |
| 2019-12-24 | 0.00                     |
| 2019-12-28 | 0.00                     |
| 2019-12-30 | 0.00                     |
| 2020-01-04 | 0.00                     |

3.3. Metering chip failure

The metering chip calculates power through voltage and current signals, and outputs active power pulses through PF pin. Voltage sampling is the voltage sampling pin of AC 220V passes through a voltage divider resistor. The live wire current sampling is generally manganese and copper sampling, and the signal passes through an anti-aliasing network composed of resistors and capacitors. In order to prevent electricity theft, according to State Grid Corporation’s regulations, the single-phase meters have a neutral line metering function. The neutral line current sampling is to convert the current signal into voltage signal through a chip resistor, and finally enter the metering chip after passing through the anti-aliasing network.

Figure 8. Voltage of charged smart meter

In the detection process, it is found that when the single-phase electric energy meter is normally powered on, the voltage value in the electric energy meter were 0.0V (see figure 8 above), the current value is 17.6mA, and the basic error is wrong. According to the above phenomenon, it was preliminarily inferred that the error was caused by the metering chip fault. After opening the cover test, it is ruled out that the metering chip and the MCU are not communicating properly, the working voltage of the metering chip is abnormal, the voltage sampling circuit is abnormal, the current...
sampling circuit is abnormal, and the MCU sends the parameters to the metering chip abnormally, which may cause the metering chip to work incorrectly. After normal reasons, the output voltage of the VREF pin of the metering chip is 0.7V (the reference voltage is 2.5V), and the C17 and C23 connected to the reference voltage VREF pin are measured to be 330Ω. In summary, the above malfunction is caused by the low reference voltage of the metering chip. Generally, the reference voltage is low due to two possibilities: one is that the capacitors C17 and C23 connected to the VREF pin of the reference voltage (as shown in figure 9 below) may become 330Ω resistors due to peripheral burrs, breakdowns, etc., and set 2.5V reference voltage is pulled down to 0.7V. Second, the 2.5V reference voltage is pulled down to 0.7V due to the internal short circuit of the metering chip.

After replacing the C17 and C23 capacitors, it was found that the electric energy meter did not improve when the C17 capacitor was changed, and the electric energy meter returned to normal when changing to C23. The resistance value of C23 was measured with a multimeter to be 2.7Ω. The voltage and current of the electric energy meter are in the table below under normal power-on conditions. The display is normal and the error is normal, so it is determined that the chip capacitor C23 is broken down and the energy meter fails.

3.4. Optocoupler failure
The CPU and the metering part are isolated by optocoupler, and the SPI bus method is used to communicate with the metering chip. The voltage, current, power and other signals are read, and then saved to the CPU. According to the pulse constant, the power required for a pulse is calculated, and the amount of electricity is accumulated. After reaching a certain level, the CPU pin sends out a low level, the driving pulse light flashes, and the pulse signal is transmitted to the meter terminal through the optocoupler to output power. The optocoupler is generally composed of three parts: light emission, light reception and signal amplification and output. The light emitting diode emits light under the drive of the input electric signal, and the light receiver generates the photocurrent. After amplification, the output electric signal is completed. The whole process is completed. Conversion of electricity.

During the detection, it was found that the pulse light of the watt-hour meter flickered normally and the error port pulse had no output. According to the preliminary inference in the field, the reason that the error port pulse has no output is that the pulse signal does not reach the error port.
According to the operating principle circuit of the optocoupler chip (see figure 10 above), it can be seen that the pulse signal output by the E2 optocoupler connected to the error port and the pulse signal of the pulse lamp come from the PULSE LED signal pin. The pulse signal of the pulse lamp is measured by the photodetector, and the basic error of the electric energy meter is normal. After checking the output waveform of the error port of the electric energy meter (see figure 11 below), it is found that the output waveform of the fault meter is shorter than the output waveform of the normal meter. Therefore, it can be inferred that the failure of the error port pulse without output is caused by the virtual welding or damage of the photocoupler E2. After replacing the photocoupler E2, the watt-hour meter returned to normal, so the damage of the photocoupler E2 was the main reason for the failure of the watt-hour meter.

4. Preventive measures for equipment quality failure

Through this article on the analysis of the typical fault, it is not difficult to see the equipment the quality failure reasons are intelligent watt-hour meter components failure, caused by damaged components may have the following reasons: One is the working voltage, withstand voltage, or current impact in the production and processing links, causing the weak current terminals of the watt-hour meter to be interfered by strong electricity, and accidentally generating a strong current or strong voltage to damage the components. Second, the electric energy meter may be squeezed, collision and other environmental factors in the process of handling and transportation may cause different degrees of impact on the components. The third is that the components themselves have quality problems, so strict control of the quality of components is the top priority of the work at this stage.

The performance testing of smart meters should not only start with personnel training, warehousing inspection, on-site testing, fault environment simulation and other methods, but also strengthen the statistics of related information of the fault table. This paper establishes a fault table data management platform through the collection of fault table reliability data, realizes all-round management and control of the fault handling process, and builds a verification based on fault data mining and multi-
dimensional visualization. The evaluation system of suppliers in the links of operation and operation, so as to evaluate the survival of the fittest for smart energy meter suppliers, urge suppliers to improve product quality and service capabilities in a targeted manner, ensure the quality of energy meters from the source, and provide reliable.

5. Conclusion
This article starts with the four typical component quality problems of smart watt-hour meter reading stop, battery undervoltage, clock, metering, and optocoupler chip failure. Based on the working principle of the components, the cause of the failure is preliminarily inferred through on-site lid opening detection. And through experimental conclusions and replacement of faulty components to verify the causes of the above failures, and finally through the establishment of a fault meter data management platform to screen the power meter suppliers, to achieve the quality control of the smart power meter components. The future goal is to further strengthen the quality control of components. Smart electric energy meter manufacturers should not only adopt components of well-known brands in the industry and strengthen and improve the inspection standards of components, but also establish component reliability testing rooms to control components. Have a complete detection and screening mechanism, and strive to prevent such phenomena from recurring at the source.

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