Correlation Analysis of Faults and Operating Environment of Electric Energy Meter

Xinxia Peng¹, Ying Liu¹, Jie Du², Qilin Liang², Fukuan Pang¹, Panpan Tan²

¹State Grid Jibei Electric Power Company Limited Power Research Institute, Jibei 100045, China.
²State Grid Jibei Langfang Power Supply Company, Jibei 100045, China

Abstract. The use of the re-entry energy meter is related to the on-site operating environment. First, the five-level quantitative standard is determined. Establish the correlation between the fault phenomenon and the operating environment, and use the software SPSS to analyze the correlation between the fault phenomenon and the operating environment. According to the size of the correlation, analyze the cause of the correlation. It provides a theoretical basis for the subsequent strengthening of quality supervision, management and production of electric energy meters.

1. Introduction
According to the 8-year replacement requirement of the smart meter rotation cycle, the low-voltage smart meter installed in the 09 specification has entered the rotation cycle. According to the results of low-voltage intelligent electric energy meter operation sampling and laboratory sampling inspection, most of the smart meters have been close to the rotation cycle even if the running time is not obvious defects, and the component quality is still in a good operating state. Therefore, combined with the intelligent table operation state evaluation technology, a more scientific and reasonable cycle replacement method can be proposed to guide the cycle reloading of large-scale smart meters, and reasonably guide the use of smart meters for residents and reduce resources under the guidance of laws and regulations.

The status change is a rotation mode for adjusting the rotation period of the meter according to the running status of the meter and the relevant verification data in the case of large-scale replacement of the smart meter by the residents, that is, selecting a batch of meters that are about to be rotated, and running through the operation. The medium state evaluation, the operation table sampling inspection, the in-use verification and other technical means determine the batch meter operation state, and if the meter status is stable, the batch schedule extension rotation can be applied.

For the failure situation of the on-site re-entry of the energy meter, we use the correlation between the variables for analysis and research.

2. Energy meter failure and its influencing factors
The environmental factors affecting the failure of the energy meter can be divided into five categories: temperature, humidity, illumination, salt spray and rain. The influence of corrosion and humidity on the performance of the energy meter, the influence of the temperature environment on the energy meter, and the performance of the solar radiation on the energy meter. Impact, the impact of rain on the energy meter, etc.
2.1. Quantitative standard

The quantitative criteria for various influencing factors are shown in Table 1.

| classification | Influencing factor | Quantitative criteria (1 means not affected by various factors, 2-5 means affected, the larger the value, the more stringent) |
|----------------|-------------------|------------------------------------------------------------------------------------------------------------------|
| Environmental factor | Salt spray | Inland distance is more than 1000Km along the coast | Inland distance 200-1000Km along the coast | Inland distance 20-20Km along the coast | Inland distance 5-20Km along the coast | Inland within 5Km of the coast |
| | temperature | The annual average temperature is below 0 degrees | The average annual temperature is 0-5 degrees | The average annual temperature is 5-10 degrees | The average annual temperature is 10-15 degrees | The average annual temperature is above 15 degrees |
| | humidity | Annual average humidity below 50% | Annual average humidity is 50%-60% | Annual average humidity is 60%-70% | Annual average humidity is 70%-80% | Annual average humidity is above 80% |
| | Rainwater immersion | No rain | / | / | / | Rainwater |
| | Solar radiation | Install indoors or have shelter from sunlight | / | / | / | Installation outside and no sunlight |

2.2. Modeling

In order to analyze the correlation between the influence factors of the energy meter, we need to establish a correlation analysis model. We take the following steps, as shown in Figure 1.

![Figure 1. Correlation between energy meter influence factors](image-url)
(1) Determine the objectives of a typical correlation analysis

In order to analyze the correlation between the influencing factors of the electric energy meter and the fault, it is necessary to collect the historical fault data of the electric energy meter. Collect old electric energy meters that have been in operation for more than 8 years in the jurisdiction of a power supply company. The operation of the electric energy meter totals more than 50,000.

(2) Design typical correlation analysis

The linear assumption affects two aspects of a typical correlation analysis. A typical correlation analysis can accommodate any metric variable without a strict normality assumption. Normality is meaningful because it normalizes the distribution and allows for a higher degree of correlation between variables.

Assume that the data of two sets of variables are measured: \( x = (x_1, x_2, x_3, x_4, \ldots, x_p) \) and \( y = (y_1, y_2, y_3, \ldots, y_q) \), and the correlation analysis matrix is shown in Table 2 below:

| x1x1 | x1x2 | \( \cdots \) | x1x5 | x1y1 | \( \cdots \) | x1y4 |
|------|------|----------|------|------|----------|------|
| x2x1 | x2x2 | \( \cdots \) | x2x5 | x2y1 | \( \cdots \) | x2y4 |
| x3x1 | x3x2 | \( \cdots \) | x3x5 | x3y1 | \( \cdots \) | x3y4 |
| x4x1 | x4x2 | \( \cdots \) | x4x5 | x4y1 | \( \cdots \) | x4y4 |
| x5x1 | x5x2 | \( \cdots \) | x5x5 | x5y1 | \( \cdots \) | x5y4 |
| y1x1 | y1x2 | \( \cdots \) | y1x5 | y1y1 | \( \cdots \) | y1y4 |
| y2x1 | y2x2 | \( \cdots \) | y2x5 | y2y1 | \( \cdots \) | y2y4 |
| y3x1 | y3x2 | \( \cdots \) | y3x5 | y3y1 | \( \cdots \) | y3y4 |
| y4x1 | y4x2 | \( \cdots \) | y4x5 | y4y1 | \( \cdots \) | y4y4 |

Here \( (x_1, x_2, x_3, x_4, x_5) = (\text{temperature, humidity, salt spray, light, rain}) \), \( (y_1, y_2, y_3, y_4) = (\text{power module, metering module, communication module, display module}) \). The relevant analysis model is shown in Table 3.

| x1 | x2 | x3 | x4 | x5 | y1 | y2 | y3 | y4 |
|----|----|----|----|----|----|----|----|----|
| x1 |    |    |    |    |    |    |    |    |
| x2 |    |    |    |    |    |    |    |    |
| x3 |    |    |    |    |    |    |    |    |
| x4 |    |    |    |    |    |    |    |    |
| x5 |    |    |    |    |    |    |    |    |
| y1 |    |    |    |    |    |    |    |    |
| y2 |    |    |    |    |    |    |    |    |
| y3 |    |    |    |    |    |    |    |    |
| y4 |    |    |    |    |    |    |    |    |

(3) Test the basic assumptions of typical correlation analysis

The linear assumption affects two aspects of a typical correlation analysis. First, the correlation coefficient between any two energy meter variables is linear. If the relationship is not linear, one or two variables need to be transformed. Second, the typical correlation is the correlation between variables.
A typical correlation analysis can accommodate any metric variable without a strict normality assumption. Normality is meaningful because it normalizes the distribution and allows for a higher degree of correlation between variables.

There are many types of faults in the key components of the energy meter, and there are many factors affecting the fault. Table 4 lists the key component fault types.

| Functional module | Fault factor          |
|------------------|----------------------|
| Power module     | Varistor             |
|                  | Thermistor           |
|                  | Safety capacitor     |
|                  | Current limiting resistor |
| Metering module  | Sampling resistor    |
|                  | Capacitance          |
|                  | Current Transformer  |
|                  | Metering chip        |
| Communication module | 485 chip           |
|                  | Thermistor           |
|                  | Optocoupler          |
| Display module   | Liquid crystal       |
|                  | Backlight            |

3. Correlation analysis
SPSS is a set of statistical analysis program software packages. It is powerful, user-friendly, easy to learn and use, and covers the entire process of mathematical analysis. It is widely used in various fields of natural sciences, social sciences and technical sciences. SPSS is suitable for marketing, sales analysis, market research, statistical reporting, quality control, scientific research, social survey, business management, teaching and administrative management, with data management, statistical analysis, data and graphics display and printing.

3.1. SPSS software analysis
Use SPSS software for related analysis, new project, data entry, variable definition process. Line = (x1, x2, x3, x4, x5, y1, y2, y3, y4) = (temperature, humidity, salt spray, light, rain, power module, metering module, communication module, display module), column = ( X1, x2, x3, x4, x5, y1, y2, y3, y4) = (temperature, humidity, salt spray, light, rain, power module, metering module, communication module, display module), for correlation analysis.

3.2. Correlation analysis
Through the SPSS software, we can get the correlation matrix. When the smart energy meter fault factor and the environmental factor are simply "positively correlated", the coefficient is greater than zero. When the two variables are "negatively correlated", the coefficient is less than 0, the coefficient is 0 means nothing, and the coefficient is 1 means fully positive correlation. The greater the correlation coefficient, the stronger the correlation. The current level of the correlation coefficient of this project is 5%.

3.3. Correlation coefficient
The correlation analysis results between various types of fault influencing factors are shown in Table 5.
3.4. Correlation coefficient analysis

The correlation analysis results between various types of fault influencing factors and faults are shown in Table 5. From the relevant analysis, the following conclusions can be drawn:

1) Relationship between salt spray and failure factor
   The salt spray is strongly related to the three faults of the power module and the metering module in the fault factor of the smart energy meter, and the correlation coefficient exceeds 0.5; under the corrosion of salt spray, the key parts of the smart meter case, the printed board, and the complicated structural form is more susceptible to the influence of salt spray environment. Once the salt mist atmosphere penetrates into the interior of the meter, the accumulation and retention of salt spray will cause it to be exposed to the salt spray environment for a longer period of time. The corrosion of the printed board is firstly from the through hole and lead. Induced at the solder joint or at the edge of the device, and randomly distributed in dots along each boundary or edge.

2) Relationship between temperature and fault factor
   The temperature is strongly correlated with the power module and the metering module in the fault factor of the smart energy meter, and the correlation coefficient exceeds 0.5; it is weakly related to the fault of the display module, and the correlation coefficient is between 0.1 and 0.3. The damaging effects of high temperature on components are mainly caused by failure caused by thermal stress, failure caused by defects at the interface and thermal growth of oxides. High temperatures accelerate the degradation of coating materials and accelerate the corrosion of metal parts. When the temperature alternates greatly, the expansion coefficient of the component is repeatedly changed, and the component fails in the repeated "thermal expansion and contraction" process.

3) Relationship between humidity and fault factor
   Humidity is strongly correlated with the power module and metering module in the fault factor of the smart energy meter, and the correlation coefficient exceeds 0.5; the humidity has the greatest influence on the shell of the smart meter. The product is in a wet environment, and the material absorbs the water vapor to cause expansion and strength. Reduced, performance changes, insulation materials can also cause electrical performance degradation.

4) Relationship between rainwater and fault factors
   Rainwater intrusion is related to the metering module in the fault factor of the electric energy meter, and the correlation coefficient exceeds 0.3; during the operation of the smart energy meter, it is necessary to take measures to prevent rain.
(5) Relationship between solar radiation and fault factors

Sunlight radiation is strongly correlated with the display module in the fault factor of the electric energy meter, and the correlation coefficient exceeds 0.5; it is weakly correlated with the metering module, power module and communication module, and the correlation coefficient is between 0.1 and 0.3.

4. Conclusion

In order to strengthen the quality supervision of electric energy meter and ensure the quality of products, it is necessary to improve the quality control and control of energy metering box from the aspect of product performance testing. Therefore, it is very necessary to propose the inspection and acceptance content according to the analysis result of the energy meter failure.

References

[1] Zhu Daqi. The principle and practice of electronic equipment fault diagnosis [M]. Beijing: Publishing House of Electronics Industry, 2004: 50-65.
[2] Long Guishan, Liu Lei, Liu Ying, et al. Research on auto-verification and intelligent storage system for smart watt-hour meter [J]. Electrical Measurement & Instrumentation, 2013, 50 (5): 95-100.
[3] Qu Jingzhi, liuweipeng, Wu Guorui, Yu Shasha. Automatic verification pipeline and intelligent storage system of based on the semi-active RFID power meter [J]. Electrical Measurement & Instrumentation, 2018, 55 (12): 104-107.
[4] Wang Libin, Wang hongying, Zhangchao. Research on the optimal maintenance frequency of electric energy meter automatic verification pipeline equipment [J]. Electrical Measurement & Instrumentation, 2017, 54 (8): 89-92.
[5] Yang Dongsheng, Lu Guanna, Ding Hengchun, Yuan Ruiming, Lv Yanguo. A fuzzy expert system for fault diagnosis of auto-verification line for electricity meters [J]. Electrical Measurement & Instrumentation, 2017, 54 (7): 94-96+102.
[6] Zhai Xiaohui, Liu Hongguo. Design and Realization of Automatic Verification Pipeline System for Intelligent Electric Energy Meters [J]. Shandong Electric Power, 2014, 41 (6): 36-38.
[7] Huang Youpeng, Fang Yanjun, Tang Meng, Sun Weiming. Research on electric energy metering equipment automatic verification flow-shop optimization scheduling [J]. Electrical Measurement & Instrumentation, 2015, 52 (18):
[8] Dong Lijun, Zhuenguo, Zhangqian, Liuxuan. Design and Application of Site Calibration System for Automatic Verification Pipeline [J]. Electrical Measurement & Instrumentation, 2015, 52 (17).
[9] Wang yonghui, Dong zengbo, Zhang yingqi, Wangjunlong, Sunchong, Wu hongbo. Research and operating maintenance of Intelligent storage system for electric energy metering [J]. Electrical Measurement & Instrumentation, 2015, 52 (7): 15-18.
[10] Xiao Tao, Zheng Fan. Application research of quality monitoring technique for automatic metrological verification pipeline system [J]. Electrical Measurement & Instrumentation, 2013, 50 (5): 72-76.
[11] MCNEILL N, DYMOND H, MELLO R P H. High-fidelity low-cost electronic current sensor for utility power metering [J]. IEEE Transactions on Power Delivery, 2011, 26 (4): 2309-2317
[12] PANDEY D, VANDANA. Improved round robin policy a mathematical approach [J]. Inter J Comput Sci Eng, 2010, 2 (4): 948-954.
[13] Zhang Yan, Huang Jinjuan. Research and Application of Intelligent Verification Line System for Electric Energy Meter [J]. Electrical Measurement & Instrumentation, 2009, 46 (12): 74-77