Research on Operation Assessment Method for Energy Meter

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Abstract. The existing electric energy meter rotation maintenance strategy regularly checks the electric energy meter and evaluates the state. It only considers the influence of time factors, neglects the influence of other factors, leads to the inaccuracy of the evaluation, and causes the waste of resources. In order to evaluate the running state of the electric energy meter in time, a method of the operation evaluation of the electric energy meter is proposed. The method is based on extracting the existing data acquisition system, marketing business system and metrology production scheduling platform that affect the state of energy meters, and classified into error stability, operational reliability, potential risks and other factors according to the influencing factors, based on the above basic test score, inspecting score, monitoring score, score of family defect detection. Then, according to the evaluation model according to the scoring, we evaluate electric energy meter operating state, and finally put forward the corresponding maintenance strategy of rotation.

1 Introduction

Smart energy meter, as an important asset among electricity metering assets and basic equipment for acquiring smart grid data, is moving forward to smart, systematic, modular and diversified development, and has huge demands. In addition, our energy meter manufacturers need to satisfy the demands of domestic and foreign customers, perform economic accounting and provide stricter product supervision and control. Therefore, higher requirements on operation reliability of the energy meter are put forward [1]. Rotation overhaul of the energy meter refers to that the energy meter shall be checked in rotation as specified so as to guarantee long-term operation of the energy meter, which will consume lots of manpower and materials. Therefore, the most urgent problem lies in operation status assessment and rotation overhaul strategy of the smart energy meter.

This paper mainly analyzes and comprehensively scores the factors affecting the operation of the energy meter according to data of multiple systems, determines the operation status according to different scores, and puts forward the corresponding rotation overhaul strategy.

2 Selection of Status Quantity of Energy Meter

Currently, status analysis of the energy meter depends on single data of regular sampling strategy, and lacks all-round status monitoring over the energy meter.

Multiple factors affect the operation status of the energy meter, and mainly include workmanship, site environment, original basic error, operation time and on-site abnormality [6-9].

This paper provides classification according to data of the existing electricity information acquisition system, marketing business system, measurement production dispatching system and other information systems (such as MDS system) as well as error stability, operation stability, potential
defects and other factors, and specific classification rules are shown in Figure 1:

The principle of error stability, operation stability principle, potential risk principle, other factors and other status selection principles, the status quantity of each system is extracted.

Basic error $S_1$: select the errors of 3 load points: (1) $U_n$, $I_n$, error $S_{1-1}$ of $\cos \phi = 1.0$; (2) $U_n$ takes Class 0.2S and Class 0.5S, 0.02 $I_n$, $\cos \phi = 0.5L$ error, $U_n$ takes Class 1 and Class 2, 0.05 $I_n$, $\cos \phi = 0.5L$ error $S_{1-2}$; (3) $U_n$, $I_{\text{max}}$, $\cos \phi = 1.0$ error $S_{1-3}$; (4) $U_n$, $I_n$, $\cos \phi = 0.8L$ error $S_{1-4}$ (optional). These errors are mainly from MDS system and summary of basic errors (if data is missing and it is impossible to make additional recording, 0.5 time of the error limit is taken by default).

Operation error $S_2$ is an error obtained during on-site real load test, and is obtained during operation, maintenance and testing of the SG186 marketing business system (site testing data and readings of energy meter).

Error dispersion $S_3$ is a rated load point of the same batch of qualified energy meters. When the power factor is 1.0, standard deviations in basic errors come from the basic summary of errors of the MDS system. The formula is shown below:

$$S_3 = \sqrt{\frac{1}{N-1} \sum_{i=1}^{N} (x_i - \bar{x})^2} \quad (1)$$

Return rate $S_4$ of the batch under complete inspection and acceptance refers to a disqualification rate of the three-phase energy meter produced by the same manufacturer in nearly 3 years, and comes from the MDS return task list. The formula is shown below:

$$S_4 = \frac{\text{Return batch of disqualified energy meters}}{\text{Total batch of supplied energy meter}} \times 100\% \quad (2)$$

Operation batch $S_5$ refers to operation fault ratio of the same batch of energy meters, and comes from MDS operation fault statistics. The formula is shown below:

$$S_5 = \frac{\text{Quantity of stopped energy meters due to quality problems}}{\text{Total quantity of energy meters}} \times 100\% \quad (3)$$

Operation time and environment are classified into 2 types: (1) $S_{6-1}$ refers to operation years with the minimum resolution of 0.5 year, and is only rounded down, for example: 0-5.9 month(s) is/are equal to 0 years, and 6-11.9 months are equal to 0.5 years; (2) $S_{6-2}$ refers to operation environment, and is classified into with/without indoor air conditioning and outdoor environment. Different weights are provided under different environment, in which the operation duration takes the operation length field of the meter service life and stock age data provided by SG186 marketing.

![Fig.1 State volume classification diagram](image-url)
business system, and new fields need to be added for installation environment in the C_METER table of SG186 marketing business system.

Family defect $S_7$ refers for confirmed influence of family defects [12]. Online electricity monitoring abnormality $S_8$ refers to real electricity abnormality discovered during online monitoring, and data come from the online monitoring module of the acquisition system. Online electricity monitoring abnormality $S_8$ refers to real clock abnormality discovered during online monitoring within 1 assessment cycle, and data come from the online monitoring module of the acquisition system. User reputation $S_{10}$ refers to whether the user is involved in unauthorized operation and metering device destruction behaviors such as electricity stealing within 1 year, and data come from the marketing business system.

3 Operation Assessment Model

On the basis of selecting the status of the energy meter in Section 2, an assessment model with a full score of 100 is established, including basic score $B$, testing score $T$, monitoring score $M$ and family defect score $F$.

3.1 Basic Score $B$

Reference objects of basic scoring $B$ are energy meter supplied by the same manufacturer, energy meter of the same batch, scored energy meter and user. As for return ratio $S_5$ of the batches of the energy meters supplied by the same manufacturer for complete testing and acceptance, the scoring formula is shown below:

$$B_1 = A_{B1} \times (1 - S_4 + 80)$$  \hspace{1cm} (4)

Energy meter of the same batch includes batch error dispersion status $S_3$ and batch operation fault $S_5$, and the formula is shown below:

$$B_2 = A_{B2} \times (1 - \frac{s_5}{0.2 \times \text{error limit}})$$  \hspace{1cm} (5)

$$B_3 = A_{B3} \times (1 - S_5)$$  \hspace{1cm} (6)

Scored energy meter includes basic error $S_1$ and operation time and environment $S_6$, and the formula is shown below:

$$B_4 = A_{B4-1} \times \frac{(\text{error limit} - |S_{1-1}|)}{\text{error limit}} + A_{B4-2} \times \frac{(\text{error limit} - |S_{1-2}|)}{\text{error limit}} + A_{B4-3} \times \frac{(\text{error limit} - |S_{1-3}|)}{\text{error limit}} + A_{B4-4} \times \frac{(\text{error limit} - |S_{1-4}|)}{\text{error limit}}$$  \hspace{1cm} (7)

$$B_5 = 20 - 2.5 \times S_{6-1} \times S_{6-2}$$  \hspace{1cm} (8)

User includes user reputation $S_{10}$, its score is based on electricity stealing and other behaviors which damage the energy meter within 1 years. Therefore, $B_6 = 0$, or $B_6 = A_{B6}$.

$A_{B1}$, $A_{B2}$, $A_{B3}$, $A_{B4-1}$, $A_{B4-2}$, $A_{B4-3}$, $A_{B4-4}$ and $A_{B6}$ are configurable, and following guarantee is provided:

$$A_{B1} + A_{B2} + A_{B3} + A_{B4-1} + A_{B4-2} + A_{B4-3} + A_{B4-4} + A_{B6} = 80$$ scores, and $A_{B1}=10$.

$A_{B2}=10, A_{B3}=20, A_{B4-1}=10, A_{B4-2}=10, A_{B4-3}=10, A_{B4-4}=0$ and $A_{B6}=10$ by default; $S_{6-2}$ are weighted under operation environment, and default weight refers to Table 1.

| Table 1. default weight | $S_{6-2} (%)$ |
|-------------------------|-------------|
| With indoor air conditioning | 100 |
| Without indoor air | 120 |
Outdoor

According to reference table 1, basic score \( B = \sum_{i=1}^{6} B_i \).

3.2 Testing Score \( T \)

Testing score is a score of operation errors of the energy meters under on-site testing. The score ranges from 100% to 0%. If the score is 100%, the operation error is far below the error limit. The testing score reference object is scored energy meter, and the corresponding status is operation error \( S_2 \). The formula is shown below:

\[
T_i = \min \left( \frac{|error \ limit| - |S_2|}{error \ limit} \right) \times A_T \times 100\% \quad (9)
\]

If \( T_i < 0 \), \( T_i = 0 \). \( A_T \) is configurable, and the default is 50%.

Testing score \( T \) is finally obtained according to the formula \( T = \frac{\sum_{i=1}^{n} T_i}{n} \), in which \( n \) refers to score of last \( n \) tests. For category I energy meter, \( n=3 \); for category II energy meter, \( n=2 \); for category III energy meter, \( n=1 \). If the testing frequency is lower than \( n \), scoring is not applicable (\( T=1 \)).

3.3 Monitoring Score \( M \)

Monitoring score is a score of operation abnormality of the energy meters discovered by the online monitoring module. The score ranges from 100% to 0%. If the score is 100%, it indicates that no operation fault occurs. The monitoring score refers to Table 2:

\[
M_1 = A_{M1} \sqrt{S_8} \times 100\%
\]

\[
M_2 = A_{M2} \sqrt{S_9} \times 100\%
\]

\( A_{M1} \) and \( A_{M2} \) are configurable, and \( A_{M1} \) and \( A_{M2} \) are 90% and 80% respectively. The monitoring score is finally obtained according to the formula \( M = M_1 \times M_2 \).

3.4 Family Defect Score \( F \)

Family defect refers to a regular problem which widely affects the service life of the energy meter produced by the same manufacturer due to same production material, production process, design concept and idea. In case of family defects, the family defect scores of the energy meters without family defects refer to Table 3 according to defect conditions.

\[
F = 1 - \frac{1 - S_7}{N} \times 100\%, \text{in which N refers to total}
\]
quantity of the family energy meter, and \( n \) refers to the quantity of energy meters with family defects (\( N > n \geq 1 \)). Family defects of the energy meter shall be judged and assessed according to the *Measures for Quality Supervision and Management of Energy Meter of State Grid Corporation of China*, and defect scores are uniformly issued by the Company’s Marketing Department. If potential family defects have been eliminated, the impacts therefrom are not considered.

3.5 Operation Status Assessment

According to the score calculated based on basic score, testing score, monitoring score and family defect score, the final status score is calculated by \( G = BTMF \), in which \( B \) refers to basic score, \( T \) refers to testing score, \( M \) refers to monitoring core and \( F \) refers to family defect score. The status of the energy meter is assessed according to calculated status score, and the judgment basis is shown in Table 4:

| Operation status | Absolute score | Cycle score of last month-cycle score of current month |
|------------------|----------------|------------------------------------------------------|
| Stable           | \([80, 100)\)  | \((-\infty, 5]\)                                       |
| Attention        | \([30, 80)\)   | \([5, 30]\)                                           |
| Pre-warning      | \([0, 30)\)    | \((30, +\infty)\)                                     |

Seen from Table 4, the sequence of the operation status of the energy meter is stable > attention > pre-warning from good to poor. When the status determined by absolute score and difference between two status scores (cycle scores of last month and current month) is different, poorer status shall prevail.

4 Patrol Inspection Strategy

According to the status of the energy meter assessed in each month, propose a rotation overhaul strategy for the energy meter, as shown in Table 5 (the cycle is 1 year in the table):

| Operation status | Rotation Overhaul Strategy |
|------------------|---------------------------|
| Stable           | Patrol inspection in doubled cycle and normal cycle |
| Attention        | Patrol inspection in 1/2 cycle and appropriate patrol inspection |
| Pre-warning      | Immediate patrol inspection |

Strategy for patrol inspection under stable status: determine the patrol strategy according to the service life. Arrange field inspection according to doubled patrol inspection cycle within 6 years during normal use, or arrange field inspection according to normal patrol inspection cycle if beyond 6 years.

Strategy for patrol inspection under attention status: determine the patrol strategy according to the service life. Arrange field inspection according to 1/2 patrol inspection cycle within 6 years during normal use, or arrange real-time status inspection, remote inspection and timely patrol inspection if beyond 6 years.

Patrol inspection under pre-warning status: arrange real-time patrol inspection and remote patrol inspection, and immediately arrange field inspection.

5. Conclusion

Considering that the operation status of the energy meter cannot be obtained in time according to the
energy meter inspection strategy, the variables affecting the status of the energy meter are multi-dimensionally considered according to data of existing mature Co system, and the status of the energy meter is assessed according to scores calculated by the model. The corresponding rotation overhaul strategy for the energy meter is proposed and auxiliary decisions are provided on the basis of evaluating the status.

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