Research on EMS Alarm Analysis and Secondary Equipment Status Evaluation

Ke Lu¹, Taotao Dai², Liancheng Wang¹, Nan Chen¹, Wei Zhao¹

¹ College of Electrical Engineering, Shandong University, Jing Shi Road No. 17923, Jinan, Shandong, China
² Shandong Hising Electric Power Technology Co., Ltd., Orson Mansion, Jinan, Shandong, China
1030890082@qq.com

Abstract. The intellectualization level and information level of the secondary equipment in the intelligent substation have been greatly improved, which is of great significance for the normal operation of the power system. However, the secondary equipment will generate a lot of redundant alarms information in the EMS system. These alarms are not conducive to finding equipment faults, and there is a lack of an active maintenance method for secondary equipment. In this paper, an intelligent analysis method of EMS alarm information is proposed. This method can find fault alarm information accurately, and we used the actual data of intelligent substation to verify it. A status evaluation method for the secondary equipment is also proposed. The method can be used for early warning of equipment failure and efficient operation and maintenance.

1. Introduction

With the rapid development of smart grid, intelligent substation has been popularized, the intelligent level and quantity of the secondary equipment of the power system have been greatly improved, and the importance of the secondary equipment to the safe and stable operation of the power system is becoming more and more important [1]. Therefore, the management, operation, maintenance and overhaul of the secondary equipment have been put forward higher requirements. It is of great significance for the stability of the power system and the sustained, rapid and healthy development of the economy and society to carry out a comprehensive monitoring and precise elimination of the secondary equipment [2].

The secondary system of the intelligent substation is very important to the safe operation of the power system, and the secondary equipment is an important part of the secondary system [3]. The secondary equipment of the intelligent substation is the equipment that protects, controls, regulates and monitors the primary equipment, which is divided into three types, the process layer, the interval layer and the station control layer, mainly including the communication device, the merger unit, protection device, intelligent terminal and so on [4]. However, because of the large number, many types and complex structure of the secondary equipment, the ability of self-checking and communication of equipment is very strong, so it will produce a lot of alarm information in the EMS system, which contains lots of redundant information [5]. Often, the alarm information that represents the equipment failure will be covered in massive information, which is not conducive to the timely and accurate discovery of the faults. Equipment failure alarm has caused difficulties for the maintenance of
the secondary equipment. Therefore, an intelligent analysis method of EMS alarm information is needed to solve this problem.

Compared with the traditional substation, the intelligent substation has great difference in operation structure, information data collection and equipment intelligence [6]. The secondary system structure function of intelligent substation becomes more complex, and the operation status of all kinds of secondary equipment is related to the action of protection when the system fails [7]. At the same time, the maintenance method based on status evaluation becomes particularly necessary because the long-term maintenance method cannot meet the actual needs of the secondary equipment in the intelligent substation. The secondary equipment has a large number of real-time operating data and historical account data, so fully utilizing these data to carry out equipment status assessment and fault warning can be useful for status maintenance and maintenance of the stable operation of the power system [8].

2. Intelligence analysis method of alarm information

EMS system has huge alarm signals. For example, a city with 100 substations, has about tens of thousands of alarm every day, and has about 50 million in a year, and the real equipment fault is only about 500 times. For the massive alarms, the selection method is mainly based on the artificial experience and the study of historical data [9], and the real device fault warning signal can be selected from this method. This method mainly includes the following three steps: field partition, keyword selection and filtering scheme.

2.1. Partition fields
First, the relevant irrelevant contents of the node, operator and supervisor are deleted by the received alarm signal, and then the field is divided.

- Alarm signal field partition: date time + type + station + content + others.
- Content field breakdown: voltage level + device or outgoing interval + device name or code + problem.
- Types: protection signal, alarm confirmation, telemetry limit, limit recovery, knife switch position, SOE, status change, switch position, communication status, remote control operation and so on.
- Others: action, recovery, closing, separation, SOE time, value, malfunction, normal and so on.

The alarm description is very detailed and can be directly positioned to the device. When the alarm signal is received, the above fields should be distinguished, and the corresponding methods should be determined according to the type of alarm. The screening is carried out in real time.

2.2. Keyword selection
Protection signal: fault, anomaly, alarm, communication interruption, working condition withdrawing, broken line, broken phase, failure, no storage energy, vanishing, voltage low, vacuum bubble leak, voltage open and jump, grounding, filing failure, time out, power outage, power loss, not work.

- Alarm signal RTU status, channel status: malfunction, normal.
- Communication status: stop, run.
- Total accident: action, recovery.
- Remote control operation: refuse to move, succeed, timeout, right.

2.3. Filtering scheme

(1) Protection signal: the "content" field is selected by keyword, which is filtered by any of the above keywords. And then observe the "other" field. If the "other" field is "action", start the timing until the next "type, station, content" field is completely the same and the "other" field is a "recovery" warning (both as a pair), before which the warning is marked "not recovered", and if "recovery" is received, it looks forward to its pair "action" warning. If the not recovered time is over 1 hour, the alarm is carried out and the not recovered time is shown in real time. The longer the time is, the higher the top display is, it is regarded as a defect, and the automatic recovery within 1 hour is regarded as no defect (the
overwhelming majority will automatically recover). If the signal after the action is still "action", the second action signal is ignored, but it should be counted in frequency statistics. The "recovery" signal after recovery is using the same principle.

Figure 1. Protection signal keyword selection process.

(2) RTU status, channel status: if the "other" field contains "fault", it is screened and start timing, until the corresponding "other" fields contain "normal" alarm, the principle is the same.

(3) Communication status: if the "other" field contains "stop", it is screened, start timing, until the "other" field is received with the "run" alarm, the principle is same.

(4) Total accident: if the "other" field contains "action", it is screened and timed until the "recovery" alarm is received in the corresponding "other" field, and the principle is same.

(5) Remote control operation: if the alarm contains "timeout" and "Refusal", it is screened and timed until the "station, content, other" fields are completely the same, and the corresponding positions are "correct" and "successful" alarm is received, with a time limit of 1 hours.

(6) Telemetry limit, limit recovery: if the "type" field is "telemetry limit", it is screened and timed until the "station, content" field is completely the same, and the "type" field is the "limit recovery" alarm, the time limit is 1 hours.

(7) SOE: comparing the time and time of the SOE in the "other" field with the date and time in the "date time" field. If the difference is more than 1 minutes, we think there is defect.

(8) Protection signal, limit recovery, telemetry limit, knife switch position, status change, switch position:

A. frequency statistics:

The same signal frequency statistics: real-time frequency statistics are carried out for the same alarm of "type, station, content" field, and one hour is received to calculate the frequency within one hour before this time. If more than 10 times an hour, frequent warning defects, such as frequent break of knife and gate, frequent limit of voltage, frequent interruption of communication.

The same station frequency statistics: real-time frequency statistics of the same warning of "type, station" field, and one hour to calculate the frequency within one hour before the time is received. If more than 50 times an hour, there are some defects in the substation which leads to more alarm at all intervals.

The frequency is displayed in real time, the higher frequency the more top displayed of the signal. If the frequency is higher than the given value, then alarm.

B. time length statistics:

It is also divided into the same signal and the same station statistics. Some alarm may have low frequency but long time. The time span of the alarm appears is real-time statistical. Each receiving one is receiving one hour before checking this time. If at least one per hour and more than 12 hours appear for a long time, it is considered to have a long time alarm defect.

The frequency is displayed in real time, the higher frequency the more top displayed of the signal. If the frequency is higher than the given value, then alarm.

(9) Other types: can be ignored directly.
3. Secondary equipment status evaluation method

During the normal operation of the secondary equipment, related basic data, equipment real time and historical data and other characteristic parameters reflecting the health status of the equipment are obtained, and the current health status of the equipment can be evaluated [10].

The data based on the evaluation mainly includes secondary equipment historical data and real-time monitoring data. According to the results of the evaluation, the short-term or long-term early warning operation of the secondary equipment is established. We will set 9 evaluation indicators, according to the different types of equipment to delimit different index evaluation mechanism, each index of the equipment is scored, the hidden danger is 3 points, the medium is 2, and the normal is 1 points. The weights of different indicators are allocated, and the final evaluation results are obtained by weighted summation.

The index and weight of the evaluation are as follows:

| Equipment history data | Real-time monitoring data |
|------------------------|--------------------------|
| Using time             | CPU load rate            |
| Fault frequency        | Delay error              |
| Severity of failures   | Humidity                 |

The index and weight of the evaluation are as follows:

- **Equipment temperature**: 0.1
- **Supply voltage**: 0.1
- **Equipment vibration**: 0.05
- **CPU load rate**: 0.05
- **Delay error**: 0.05
- **Humidity**: 0.05
- **Using time**: 0.3
- **Fault frequency**: 0.2
- **Severity of failures**: 0.1

The formula of evaluation score is:

\[ y = \sum w_i x_i \]  

In this formula, \( y \) represents the evaluation score; \( w \) represents the weight of each index; \( x \) represents the evaluation value of each index; \( i: 1-9 \).

The early warning mechanism and maintenance strategy are determined by the evaluation results. After getting the evaluation score, the warning level of different grades is divided according to the score, as the following table shows. In addition, equipment that is longer than the equipment life requirement needs to be replaced immediately.

| Score degree | Maintenance measures               |
|--------------|-----------------------------------|
| <1           | Normal maintenance                |
| 1-2          | Hidden danger; Need to be overhauled regularly |
| >2           | Serious; Need to be repaired or replaced immediately |

Figure 2. Equipment evaluation index setting.
4. Verifying the alarm signal analysis method
To verify the effectiveness of the proposed EMS alarm analysis method, we used the actual data of a major provincial city between January the 1st and January the 13th in 2017. The data covers a 13 day time period, has a total of 1341065 alerts, and it includes 25 actual failures. Using the proposed method, we successfully founded 20 out of the 25 failures, and the accuracy rate reached 80.0%. Among them, the accuracy rate of SOE and remote control operation was 100%. The method was proved highly accurate and feasible.

5. Conclusions
In view of the important significance of the secondary equipment maintenance for the safe and stable operation of the power system, an intelligent analysis method of EMS alarm information is proposed in this paper. The proposed method can find out the fault alarm information more accurately, and use a large number of actual data to verify it. In addition, a general state evaluation method of secondary equipment is proposed, which makes it feasible to make a simple assessment of the state of the equipment. On this basis, we can carry on the fault early warning, assist the maintenance strategy and realize the efficient operation and maintenance.

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