Assessment Index System for Optimal D5000 Alarm Data Platform

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Abstract. Nowadays, alarm information collected by dispatching and control systems is increasing substantially and the problem of frequent and false information happens occasionally, which may influence the operation status analysis of power grid and the following work of big data mining and cloud-computing. Thus this paper proposed an optimal D5000 alarm data platform, using the intelligent techniques like alarm restraining, information folding, etc. Besides, assessment index system was also established to analyse the optimized effect of the alarm data processing system, adopting the fishbone diagram and improved Grey incidence approach. The practical results show that the optimal platform is practical and valuable in following aspects: eliminating redundant and interference information, reducing the man-made missing or judging problem of urgent and important information, improving the big data analysis and management, and so on.

1. Introduction
Under the integrated mode of dispatching and control, real-time alarm information increases sharply, equipment abnormal data sent frequently and mistakenly and plenty of simultaneous interference information produced during power grid fault, which pose great challenge to the normal equipment supervision work [1-2].

Faced with this, Tianjin Chengxi Power Supply Company introduced an advanced smart grid dispatching and control system (hereinafter referred to as D5000 systems) in 2014. As a big data platform, D5000 systems are of great use in collecting, storing and processing massive real-time state data [3-5], bringing a new concept for solution of big alarm data information analysis and management.

This article proposed an optimal D5000 alarm data platform, which adopts the intelligent techniques, including uploading-time delay, single-point or interval restraining, automatic alarm folding, etc., to solve relevant problems in alarm information processing of substation equipment [6-8]. Assessment index system was also built to analyse the optimized effect of the alarm data processing system, compared with ON2000 systems. The fishbone diagram and improved Grey incidence approach are applied to simultaneously consider subjectivity and objectivity [9-11].

2. D5000 alarm service

2.1. Alarm service function
Supervision alarm refers to the alarm terms uploaded to the alarm window after the alarm information processing, which is also the key attention object of supervision operation, including operation state change, future system prediction, equipment supervision and control, dispatcher operation records, etc. [12-14].
Figure 1 displays the specific process of alarm service function in D5000 systems. The alarm service serves as a central nervous control system which is capable of receiving alarm source information (including sequence of event SOE, protection action and change signal, etc.) sent by application programs (SCADA, PAS, AGC, etc.), assigning tasks to the connected alarm clients, and notifying them to adopt corresponding alarm behaviors.

2.2. Alarm information classification
According to the requirement of State Grid Enterprise Standard “Q/GDW 11398-2015 Substation Equipment Supervision Information Specification” [15], five alarm levels of accident, abnormal, out-of-limit, change and notification are classified by the effect on the power grid and the equipment and displayed in the real-time alarm window by different color and category. See Figure 2.

Figure 2. Real-time alarm window display of supervision information.

The daily work of supervision personnel is to monitor the real-time alarm information in the “comprehensive alarm” window, which displays the accident, alarm, out-of-limit and change information, and adopt corresponding treatment measures according to the alarm category. By checking the alarm type, workload of supervision personnel can be reduced effectively.

2.3. Alarm filtering function
In the process that D5000 alarm information is received in the middle layer via the alarm service, the information can be processed through the background file configuration and self-defined filtering function.

| Filtering Condition   | Filtering meanings                                                                 |
|-----------------------|------------------------------------------------------------------------------------|
| st filtering          | The substation state attribute is non-supervised state in the real-time database  |
| if_sum_group filtering | “Uploading to alarm-window” is not selected in the alarm definition                 |
| warn_type filtering   | Alarm information of such certain type is not configured in “detail.ini” file      |
| restrain_flag filtering| In case of alarm restraining or filtering due to other reasons, the “alarm_server” program assigns values (the value larger than 0 indicates restraining) |
| occur_time filtering  | Alarm time is 10mins later or 10s earlier than the scada host                      |
Table 1 just lists several filtering conditions and the corresponding meanings. By setting the specific filtering condition of alarm data, redundant and interference information could be effectively filtered, which helps to reduce supervision risk of massive alarm information within a short time, release the occupied system resources and improve the system operation efficiency.

3. D5000 alarm optimal processing
Based on D5000 alarm service, the optimal data platform adopted several optimized measures for alarm information processing, including uploading-time delay, single-point or interval restraining, automatic alarm folding, etc. The uploading-time delay and single-point or interval restraining can be achieved by setting the filtering parameter restrain_flag, as shown in Table 1, while automatic alarm folding is achieved by further modifying conditions in the configuration file.

3.1. Uploading-time delay
The alarm information should be delayed several seconds to upload to real-time alarm window when the signals acting frequently and then resetting immediately. Figure 3 shows the specific time-delay processing flow. Supervision personnel judge whether the received alarm information needs time-delay setting; then judge whether the resetting information is received in the time-delay period. When the time-delay for alarm information is set and the resetting information is received within the time-delay period, the information can be filtered, which is favourable to monitor the alarm information in real-time and treatment it timely.

![Flow diagram of window-uploading time delay for alarm information.](image)

In actual application, there is mainly the following alarm information, which can be processed by setting the uploading-time delay:
1) The associated signals produced during equipment operation, which are usually instantaneous information. Generally a 10s time-delay processing method is adopted;
2) The voltage, current and other telemetry out-of-limit data. A 30s time-delay processing is used to shield the out-of-limit information which can be reset within the stipulated delay period;
3) Abnormal simultaneously or out of service of one communication channel can be filtered. Only when both 101 and 104 channels are disconnected, the information should be displayed in real-time alarm window;
4) During telecontrol of some substations, the tap switchgear may be short to 0 in the lifting process due to equipment cause. Such information should be filtered by a 10s time-delay.

3.2. Single-point or interval restraining
There is mainly 2 alarm information restraining methods in D5000 systems:
1) Equipment listing processing, mainly used in secondary equipment overhaul and test to shield a large amount of debugging signals produced within a short time and avoid the fault judgment of the equipment true condition.
2) Single-point, interval and even substation alarm restraining, mainly targeted to frequent information caused by abnormal equipment operation to avoid the related signals frequently uploaded to the alarm window and release the occupied alarm window space.
Table 2 displays the data structure of supervision information, i.e. the real-time non-recovery action record table. The above 2 restraining methods can be achieved by separately configuring the alarm parameter reserved_2 and restrain_flag to display results required by users in the alarm window.

**Table 2.** The Non-recovery action record structure of alarm information.

```c
typedef struct real_warn_rec_new_scada
  // Structure of action non-resetting table
  {
    long id;    /* Keywords */
    long occur_time;    /* Occurrence time */
    ......
    int restrain_flag; /* Alarm restraining tab */
    int if_fg;  /* Whether to reset */
    ......
    int reserved_2; /* Tag type */
    long dev_id;    /* Signal id */
  } REAL_WARN_REC_NEW_SCADA;
```

Equipment listing property is shown by reserved_2, and the value is the tag ID. In case reserved_2 <=0, the information is not listed or filtered, otherwise, find out whether the tag ID has the alarm restraining property, filter it if any.

Single-point and interval alarm restraining just focus on the value of restrain_flag. When 1, 2 and 3 was separately assigned to restrain_flag, it indicates single-point, interval and substation restraining respectively.

The restrained or listed alarm information should be shown in the corresponding alarm information summary list, including substation name, information name, restraining or listing time, etc. Supervision in the normal state will be recovered automatically after restraining relieving and alarm information also displayed in the “comprehensive alarm” window.

### 3.3. Alarm information folding

Single-point or interval alarm restraining method still needs supervision personnel to perform manual judgment and restraining operation on the uploaded information. Therefore, a more intelligent and automatic folding method is proposed to effectively solve the problem of frequent alarm information by folding the redundant repeated information within a period, classified into two types: real-time alarm information folding and designated alarm information folding.

Only the newest folded alarm information is displayed in the alarm window, including folding tab, newest alarm time of the folded alarm, folding time, etc., as shown in Figure 4. Meanwhile, the information will keep normal uploading sequence, without affecting the time sequence analysis of the supervision information.

![Figure 4. The alarm information folding display in real-time alarm window.](image)

Information folding calculation is performed by the alarm folding rule set in the configuration file to judge whether folding information is required. If the alarm information only acts and is reset for one or two times within 5min, it will be displayed normally; if the alarm information acts and is reset for no less than three times, it will be provided with the folding tab and uploaded to the alarm window.

**Table 3.** The Non-recovery action record structure of alarm information.

| Type | Name  | Description   |
|------|-------|--------------|
| long | dev_id| Signal id    |
Table 3 shows part of basic configuration information about the alarm-folding rule in D5000 systems. By acquiring minimum interval and minimum folding times as the comparison conditions for folding calculation, alarm-folding analysis is performed. The folded alarm information can be displayed by right clicking the option “Inquire alarm folding detailed information” to inquire corresponding alarm information from the background shared memory by searching for signal id, folding times, start time, etc.

4. Assessment index system

Assessment index system was established to analyse the optimized effect in D5000 systems and the fishbone diagram was used to brainstorm all the possibilities that could cause the effect. Besides, an improved Grey incidence approach is applied to evaluate the performance of big data processing in D5000 systems compared with that in ON2000 systems.

4.1. Index system analysis

Establishing an index system should follow the five principles, including systematic, scientific, independence, adaptability and comparability, and ensure that the indexes have clear meanings and could calculate easily.

This paper adopt the fishbone diagram to analyse the factors causing the optimized effect, in which the various causes are grouped into categories and cascade from the main categories, flowing towards the effect, forming what resembles a fishbone appearance [9].

Figure 5 shows the main factors influencing on big data analysis and management. Considering three categories of D5000 systems, supervision personnel and optimized methods, the index system was built up, specific indexes are shown in Figure 5.

4.2. Index weight calculation

The assessment index weight is an important link in comprehensive evaluation. Firstly, Delphi method is adopted to set the index weight and the improved Grey incidence approach is chosen to reduce artificial factors, which makes subjectivity and objectivity simultaneously considered [10]. Specific steps are as follows:

1) Determine the evaluation indicators and employ experts to make the experience weights. See Equation 1, the matrix with n indexes and m experts.

| long | occur_time | Signal action time |
|------|------------|--------------------|
| int  | ffold_type | Folding type       |
| int  | fflod_time | Minimum interval of alarm-folding |
| int  | fflod_num  | Minimum folding times of alarm interval |

Figure 5. The alarm information folding display in real-time alarm window.
Determine the reference sequence \( A_0 \), selecting maximum weight values from the empirical judgment matrix for each index, as shown in Equation 2.

\[
A_0 = (a_{01}, a_{02}, \ldots, a_{0n})
\]

2) Determine the reference sequence \( A_0 \), selecting maximum weight values from the empirical judgment matrix for each index, as shown in Equation 2.

3) Calculate the distance between all the index sequence \( A_i, A_j, \ldots, A_n \) and the reference sequence \( A_0 \), as shown in Equation 3.

\[
D_{ik} = \sum_{j=1}^{n} (a_{ij} - a_{0j})^2
\]

4) Obtain the weights of each index and do the normalization. See Equation 4 and 5.

\[
\omega_i = \frac{1}{1 + D_{ik}}
\]

\[
\sigma_i = \frac{\omega_i}{\sum_{i=1}^{n} \omega_i}
\]

With the opinions of 10 experts, the weights of each index are finally determined, as shown in Table 4.

### 4.3. Index score and result

According to the experts’ opinions, this paper adopted Delphi method again to obtain the discrete index score standard, and did the curve fitting with “Curving fitting tool” of Matlab. The index weight and score function are shown in Table 4.

**Table 4. Index weight and score function of influencing factors**

| Index Name               | Index Weight | Index Score Function                  |
|--------------------------|--------------|---------------------------------------|
| Operation security       | 0.1124       | \( y=0.0007x^3-0.093x^2+4.51x \)      |
| Interface friendliness   | 0.0857       | \( y=0.0054x^2+0.46x \)              |
| System usability         | 0.1011       | \( y=-0.011x^2+2.1x \)              |
| Processing accuracy      | 0.1429       | \( y=x \)                             |
| Work efficiency          | 0.1254       | \( y=0.0054x^2+0.46x \)              |
| User satisfaction        | 0.0955       | \( y=-0.011x^2+2.1x \)              |
| Measure intelligence     | 0.1314       | \( y=0.0007x^3-0.093x^2+4.51x \)      |
| Information decrement    | 0.1124       | \( y=-0.024x^2+2.97x \)              |
| Function feasibility     | 0.0932       | \( y=-0.024x^2+2.97x \)              |

According to the score function given in Table 4, the score for each index can be calculated and the overall score can also be obtained, which comparing the practicability of optimized measures in D5000 systems with that in ON2000 systems, as shown in Table 5.

**Table 5. Evaluation results of index system**

| Evaluation result | D5000 systems | ON2000 systems |
|-------------------|---------------|----------------|
| Operation security| 92.46         | 77.63          |
Interface friendliness  78.16  47.04
System usability  95.63  88.64
Processing accuracy  88.03  65.12
Work efficiency  71.36  36.50
User satisfaction  96.48  90.68
Measure intelligence  96.75  79.62
Information decrement  86.99  39.15
Function feasibility  91.65  85.05
Comprehensive score  88.53  67.03

5. Conclusion
To analyse the optimized processing effect in the D5000 alarm data platform, this paper introduced several optimized techniques including uploading-time delay, single-point or interval restraining, alarm information folding, etc., and established the assessment index system and evaluation method, using the fishbone diagram and improved Grey incidence approach.

According to the data in Table 5, all the indexes were improved in D5000 systems, especially the three indexes of interface friendliness, work efficiency and information decrement, whose scores are separately promoted to 78.16, 71.36 and 86.99, compared with 47.04, 36.50 and 39.15 in ON2000 systems. Besides, the comprehensive score of D5000 systems was 88.53, which has a 21.5 improvement compared to that in ON2000 systems, indicating obviously the intelligence and feasibility of optimal D5000 alarm data platform.

The practical results show that the optimal alarm data platform is practical and valuable since redundant and interference information was eliminated effectively, supervision information amount and the man-made missing or judging problems were both reduced and big alarm data analysis and management was significantly improved. Meanwhile, it provided reference for online application work of D5000 systems; thereby achieve great generalization and reference significance.

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