A logical reasoning-based method for sensing the operating status of equipment

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Abstract: Grid equipment monitoring is to achieve comprehensive perception, rapid analysis and accurate disposal of grid operation status. As the scale of the grid continues to expand, many problems such as low efficiency in single point-based alarming, complicated and difficult process, irregular work norms, etc., have occurred in the current operating mode, which greatly restricts the improvement of management level of monitoring operation. Based on the correlation between substation monitoring information and monitoring equipment operation, we establish the correspondence between primary equipment such as main transformer, busbar, line and capacitor and the corresponding telemetry such as current, voltage, active power, reactive power and frequency. Then we analyze the occurrence mechanism of power grid equipment operation events, sense the equipment operation status, and realize timely and accurate sense and push of equipment operation defects and faults, thereby improving operational efficiency of monitoring devices.

1. Introduction

With the expansion of the scale of the power grid, equipment sensing means are becoming increasingly perfect. When we establish a large number of sensors and collect monitoring information, many monitoring data frequently appears on the screen, and in a disorderly form, especially in case of interlocking failure of devices, multiple equipments give alarms at the same time. This undoubtedly brings great interference to the monitoring personnel to identify the equipment status [1]. By studying the intrinsic logical relationship between equipment status and associated signals, extracting the typical description of monitoring information, summarizing the monitoring information alarm mechanism, mining the logic of alarm information time sequence system, signal primary and secondary division, combination relationship between signals, interference information identification, etc., and constructing the equipment status perception model. The model is further validated and improved by analyzing the frequency and sequence of specific information through historical fault inversion, simulating the process of monitoring information when a fault occurs, and bringing it into the equipment condition-awareness model [2].

The information event association rules are extracted, the information event association rules library is defined, the monitoring signal clusters are intelligently split and summarized, and the grid events are intelligently judged according to the information event deduction logic [3]. The accuracy and completeness of monitoring information can also be inferred backward based on the definition of grid events and information event association rules, and the frequency and other characteristics of
specific information events can be analyzed to further complete grid event prediction and provide early warning for stable grid operation [4].

2. Monitoring information and event model

The existence of a necessary connection between monitoring information and events is a prerequisite for designing a rule base of information events [5]. Monitoring information is generated from events, and the generation of events must be accompanied by the reporting of monitoring information. The monitoring information event rule base achieves the purpose of identifying events through information by identifying the event source information, supplemented with discriminatory rules, and making accurate judgments about the nature and level of events [6]. Meanwhile, we can also design a heuristic learning mechanism to improve the event-information correspondence by using historical events and standardized monitoring information. And in this way, we can achieve the purpose of using events to discern missing and wrong monitoring information.

2.1. Event source identification rules

The event sources are divided into two categories: protection action events and operation control events [7]. The main focus of this study is on the rules of protection action events. The identification of the protection action event source can be based on the signals of “protection exit”, “tripping exit” and “reclosing exit”. If there is an overhaul identification field, it can be temporarily unrecognized. Define event source characteristics:

\[ S_{jy1} = \text{“Protection exit action”}; \]
\[ S_{jy2} = \text{“Trip exit action”}; \]
\[ S_{jy3} = \text{“reclosing exit action”}; \]

... 

2.2. Event-related information extraction rules

From the event source information to initially determine the possible occurrence of a specific grid event, according to the characteristics of the event source information in the massive monitoring information to extract relevant information, to provide a basis for event identification and judgment. Take 500 kV line protection action (single trip and single success, as shown in Fig.1) as an example to list event source information extraction rules. According to the event source (S\text{\text{y1}} for example), the event characteristics of the monitoring information are extracted: the field of “belonging to the station/belonging to the interval” is extracted and stored as the characteristic quantity \((S_{\text{sta}/})\).

Bay1, (S\text{\text{sta}/}Bay)2, ..., (S\text{\text{sta}/}Bay)m, ..., (S\text{\text{sta}/}Bay)n. The domain of the “event moment” is extracted and stored as the feature quantities Tim1, Tim2, ...

2.3. Monitoring information filtering method

The time period of the event as the search width, screening the event core signal. According to the extracted Tim1, Tim2, ... determine the event time window boundary, and the default forward or backward spread 5s (spread time can be set, (Default 5 s, max 10 min), as the search boundary of the event time window monitoring information. Create a new event signal set and store all monitored signals within the search boundary into this event signal set. Search all relevant monitoring letters according to the characteristic quantity \((S_{\text{sta}/}Bay)x\)

The information is listed in chronological order in the event signal set.

2.4. Event-assisted discriminatory rules

Confirmation or identification of an event based on the event source is not enough, the event source information indicates the emergence or start of the event, to identify the development process and the outcome of the event requires additional event-assisted discriminatory rules. 500 kV line protection action (single-hop single-reclosing success, shown in Fig. 1) as an example of the collection of the
first and second Qinghai set of protection exports on the line side, the first and second sets of protection exports on the opposite side, the side of the middle and side Qinghai switch action, the opposite side of the middle and side switch action predefined rule combination (Qinghai rule combination can be edited), indicating that the event identification success, confirming the event "(line Single-phase transient fault occurred in (line interval), successful reclosing"

2.5. interval correlation judgment rule
When the complex power grid fault, monitoring information involves multiple stations, multiple intervals, monitoring signals are complicated, the goal of the study is to separate and identify the monitoring information in the massive monitoring signals as a unit of events, it is necessary to define the correlation interval involved in various events, and exclude the interference of irrelevant signals.

The event "500 kV line protection single-phase transient fault, Coincident succeeded!" was taken as an example for the explanation:

① Confirm the event source generation interval according to the monitoring information entry where the event source is located, such as "XX station/500 kV XX line 1";
② Find the names of the stations at both ends of the line according to the line interval names, and write them down as Sta_1 and Sta_2;
③ Find the associated circuit breaker number according to the line interval name, for 3/2 wiring, 2 circuit breaker intervals are associated on each side.

The 2 stations, 2 line intervals, and 4 breaker intervals associated with this event can be found through steps① to ③.

3. Information eventing algorithm
Information eventing is mainly composed of waiting for alarm interruption [4], extracting and verifying event sources, creating new event signal sets, defining time windows, filtering associated signals into event signal sets, core rule judgment, event display and pushing and monitor confirmation.

3.1. Waiting for alarm interruptions
Wait for an interrupt and resolve the first type of alarm signal “content” field. After excluding the maintenance and debugging signals, search for the "protection exit action" field in the content field, and wait for the next interruption if there is no protection exit return; if the "protection exit action" field appears in the content field, then enter the event source extraction.

3.2. Extraction/verification of event sources
Extracts the alarm message containing the field "protection outlet action" from the field "belonging to the plant" and stores it in the variable Substation_val1; extracts the field "belonging to the interval" and stores it in the variable Bay_val1. The content of this alarm message (between voltage level and "/" mark) is extracted and stored as Main_val. If Main_val ends with the word "line", the value will be assigned to the variable ACLine_val. Verify the values of the StaSta and EndSta fields corresponding to ACLine_val in the AC line segment table, which should be up to One less is consistent with Substation_val1 or not.

3.3. New event signal set (confirm event subject and associated equipment)
Take the EMS library of traditional dispatch automation system as an example, the AC line segment x1, AC line endpoint x2, plant station x2 and circuit breaker x4 associated with the event source can be found by the node number.

3.3.1. Principle of plant station inquiry
Find the StaSta and EndSta domain values corresponding to ACLine_val in the AC Line segment table, and save the one that is not consistent with Substation_val1 as Substation_val2.
3.3.2. AC line endpoint query principle
In the AC Line Endpoint table, find the two AC line endpoint names (stored as CLineDot_val1 and ACLineDot_val2) and node numbers (stored as Node1 and Node2) that match the "AC Line Segment" field.

3.3.3. Circuit breaker query principle
Find the breaker in the breaker table (Inode==Node1 or Jnode==Node1) and Substation==Substation_val1, cache as Breaker_val1_1 and Breaker_val1_2. Find the circuit breaker of (Inode==Node2 or Jnode==Node2) and Substation==Substation_val2, and save as Breaker_val2_1 与 Breaker_val2_2. Save the verified ACLine_val as the event body. Store the primary equipment associated with it (AC line segment x1, AC line endpoint x2, plant station x2, circuit breaker x4) as associated equipment. A new event signal set (event signal set number + 1) is required for each event subject appearance, as shown in Table 1.

3.4. Define the time window
The custom parameter buffer_time is the time window. The default value of buffer_time is -5~+10s, and the value before and after can be edited. For repeated accesses to the same event signal set, buffer_time is extended by 1s before and after (the extension increment should be editable), and buffer_time is reset and returned to "wait for alarm interrupt" after reaching the upper threshold.

3.5. Event display/screen push
After the successful judgment of the standard event logic, the standard events matched by each event signal set are displayed in a pop-up window in the form of a list; after the display of each standard event result, the visual judgment of all the associated equipment of the event (e.g., the plant map where the equipment is located) needs to be pushed.

4. Examples of Application
4.1. Signal screening
According to the process of monitoring event extraction, the following alarm was received in the "start" state: xxxx-xx-xx 18:24:49.150 Qinghai. The first protection RCS-931G protection outlet was activated in Puti/500kV.

(SOE) (received at 18:25:11 on xx/xx/xxxx).

Since this alarm contains the field "protection outlet", it is classified as a protection action event and extracts "Qinghai. Olive/500kV.Lampu I line protection outlet" as event source Sjy1, and "Qinghai. Line 1" is assigned to ACLine_val. The line as the main event, according to the query principle to find the line directly related to the AC line section x1, AC line endpoint x2, plant station x2, breaker x4, and the new event signal set (No. 1 event signal set) and event-related equipment set.

In the predefined time window of -5~+10s, based on the content domain of the associated equipment, 50 Type 1 alarm signals and 4 Type 4 alarm signals can be extracted from the 3272 upper window alarm signals 15s before and after the incident source signal, and stored in the event signal set No. 1 as an auxiliary criterion.

4.2. Rule judgment
The defined standard signals are compared with all the signals in the event signal set No. 1, and the flag bits of all the standard signals in the event signal set No. 1 are obtained. The logical Boolean values for each type of standard event are calculated by using the standard signals (with flag bits) of the event signal set #1 with the predefined logical block diagram. The calculated Boolean value is 1, which means that "the line instantaneous single-phase ground fault (single-hop reclosing success)" event is established.
5. Conclusion
The previous analysis of the common rules of monitoring information generated by power system grid events, and the establishment of a basic monitoring information rule base is the basis of information event. Algorithmic description of association rules, forming a library of executable rule scripts to initiate the information eventing process. We further build the information-event association engine, study the sequential information-event association method, and form the information-event matching rules. Continuously develop the logic editing module of information-event association rule base and establish the logic self-checking mechanism. Research event detection mechanism, establish a common interface to the rule base, so as to form a complete building maintenance and application chain.

Fund Project: Supported by Science and technology Project of Qinghai Electric Power Company, State Grid(5228021900KJ)

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