Prediction and analysis of device failure alarm based on Intelligent Expert System

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Abstract

Based on the classification, processing and reasoning of the alarm information of the smart substation equipment when the fault occurs, the intelligent alarm of the fault is realized. In this paper, the working process of the intelligent alarm was sorted out, and according to the severity level of intelligent substation alarm information, the staged processing of the information was carried out, and the alarm information was displayed. Then through analyzing the SCD configuration file of the intelligent substation, the secondarynetwork topology was drawn and then it was interconnected with the alarm information, thus narrowingthe positioning scope of the fault point. Later, the reasoning knowledge base was established based on the intelligent alarm expert system, so that the fault could be quickly located and eliminated when the alarm occurred. The effectiveness of the method was verified by practical reasoning cases.

Keywords*: Intelligent expert system, Equipment failure, Warning prediction*

I. Introduction

The realization of many functions of a smart substation is based on the collection and analysis of a large amount of information, and its advancement is supported by a large amount of data. However, there is also a problem. If the alarm information generated by a smart substation is not classified, filtered and judged, the monitoring page may be occupied by a large amount of alarm information in the case of power system failure. Faced with a full screen of massive alarm information, it is difficult for O&M personnel to quickly find critical fault information and locate the fault point.

To solve these problems, based on the description of the function and composition of the alarm system, the alarm information in the event of an accident or anomaly in the power grid was sorted out, classified and displayed according to the emergency degree of the fault and the handling measures, so as toreflect the operation status of the power grid equipmenttimely and accurately; Then fault alarm was carried out through network topology analysis, information association and intelligent reasoning of the smart substation.

II. Intelligent Alarm System Analysis

Compared with traditional substations, the distinctive advantageof smart substations is the ability to collect a large amount of information, then monitor the interior of the substation continuously, and record all the data. However, a large amount of data and various types of information are generated during a fault. If the data isn't distinguished, arranged, and optimized, it will be difficult to find the information that can truly identify the fault cause and fault point.And the role of the intelligent alarm system is to filter the information when the smart substation has a failure, then select the useful information, help operation and maintenance staff quickly locate fault types and fault causes, and finally provide solutions to the fault, so as to lighten the burden of the operation and maintenance staff, reduce the duration of the fault, and ensure that the intelligent substation can work in normal working condition furthest.
Figure 1 shows the workflow of the intelligent alarm system. A data acquisition system was included in the smart

substation to collect the data representing the operation of the equipment in the substation. After obtaining these data, the invalid information of some non-fault classes was removed through information filtering. With the help of expert system, particle swarm optimization algorithm, genetic algorithm and other intelligent algorithms, and combined with the current database, the fault analysis was carried out on the effective information after screening, and the results obtained from the analysis were presented in the form of documents, charts and other forms, so that the operation and maintenance personnel could handle system faults based on the fault results.

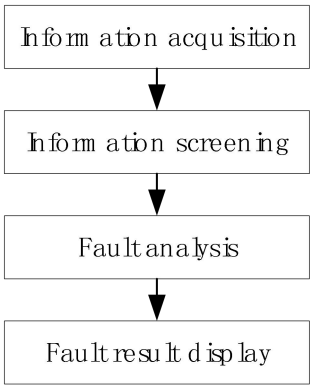

Fig 1: Workflow of the intelligent alarm system

III. Classification and Processing of Alarm Information

Compared with conventional substations, smart substations have combined units, smart terminals and communication networks. In the classification, the information related to conventional protection and measurement and control devices that the operation and maintenance personnel are familiar withwas separated from the information of newly added equipment in smart substation, so that the operators could quickly adapt to the alarm information of the smart substation.

The classification of alarm information should ensure thatthe real working condition of the equipment can be identified as quickly as possible and the number of alarm information can be reduced to the maximumwhen the fault occurs in the smart substation. Based on this principle, the intelligent alarm information of the smart substation can be divided into 6 categories [6-8].

(1) Accident alarm information. This kind of information refers to the signal that the action of the control unit of the primary equipment in the power system leads to the change of the operation state of the equipment in the smart substation, mainly including the action signal of the primary equipment operation failure, the action signal of the relay protection device, the action signal of the safety automatic device, as well as other serious fault signals. When such alarms occur, the staff must immediately monitor and handle the fault.

(2) Device running alarm information. This kind of signalshave a correlation with the operation parameters of the equipment in the power system, and their working value exceeds the allowable operationrange, including the current, voltage, main variable oil temperature, bus differential current, spring pressure of the electrical equipment.

(3) GOOSE alarm information. This kind of information is the new information of smart substations, and the main interaction is the switching position, protection tripping and alarm information. When GOOSE link communication is abnormal, the operators should quickly locate the equipment associated with the communication and the scope of influence.

(4) SV alarm information. This kind of information is the new information of smart substations, and the interaction

is the ac quantity sampling value. If the SV data is abnormal or the two SV data channels are inconsistent, the operation of the control device will be affected, so is should be handled immediately.

(5) Position information of switch breaker. This type of alarm information mainly reflects the status of the device.

(6) Operation record information. This type of alarm information mainly aims at the login and logout operations of users in the monitoring system. In addition, some of the signals accompanying the general operation of the equipment are also included.

IV. Intelligent Alarm Application Technology

(1) Information association based on the network topology

Smart substations adopt IEC61850 standard, and the whole station configuration file SCD contains the secondary equipment information of the whole substation and the network information of the substation; The SSD file also expresses a device connection for the whole substation.

Based on the network configuration of the station control layer and the process layer of the SCD file, the network connection relationship between the equipment and the station control layer, the interval layer and the process layer can be clearly obtained. Then it distinguishes whether the connection type ofthe links is networking mode or point-to-point link mode. At the same time, it also knows the connection relationship of physical ports.

The network topology diagram depicts the connection relationship of secondary equipment in the substation. Combined with the primary main wiring diagram, it can understand the secondary equipment of the whole station as well as the cooperation relationship with the primary. Then the alarm information can be connected to the network topology to visually express the fault coverage.

The smart substation equipment and communication related alarm information are combined with the communication link management of the network topology of the whole station. When the communication link generates alarm information, the alarm information can be displayed in the GOOSE/SV alarm window, and the fault location of the GOOSE/SV network link can also be clearly seen in the network topology.

Similarly, the alarm information of a primary device fault, such as a short-circuit jumper, can also be displayed on the primary topology.

Based on the information association of the network topology, when the system is running, users can better understand the working status of the smart substation through the logical relationship between devices. When the alarm information appears in the substation, the cause of the accident can be found in time by means of the correlation relationship, and then the solution to the problem can be found efficiently.

(2) Intelligent Alarm Reasoning

Intelligent alarm reasoning of smart substations is completed by an expert knowledge base. First of all, the reasoning model is established. Secondly, the operation data of the smart substation is collected, and based on this, these data are analyzed. Thirdly, the action type of the device alarm is obtained by single event reasoning and multi-event correlation analysis. Finally, the switch jump and closing actions are analyzed, so as to achieve the purpose of intelligent alarm reasoning.

1) Substations based on intelligent expert system

Smart substation expert system belongs to computer information monitoring system, and its workflow is shown in Figure 2. The main function of the substation expert system is to complete the judgment, reasoning and processing of substation accidents with the help of relay protection experts and information mining experts, and these accidents are difficult to be expressedby general mathematical models. Experts make rules for the alarm information of smart substations with the help of a man-machine interface.

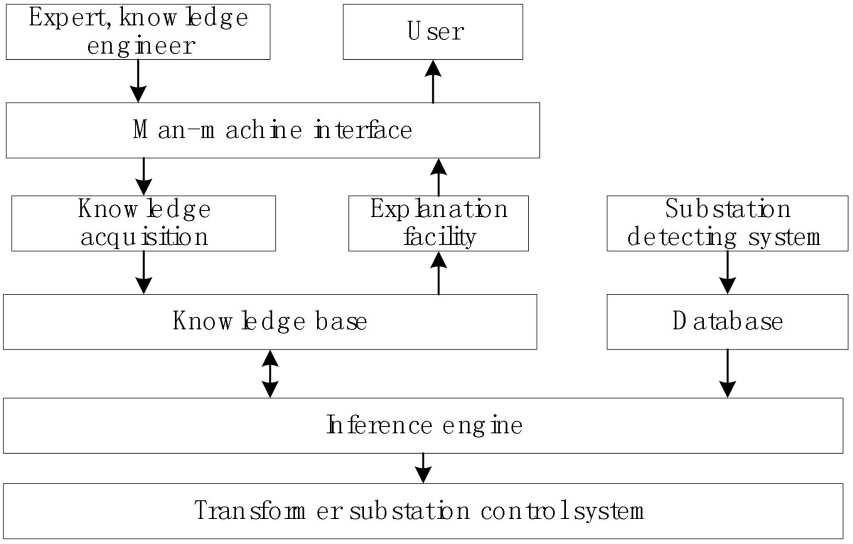

Fig 2: Workflow of expert system

2) Knowledge base

The function of a knowledge base is to store a large amount of expertise provided by experts. The quality of a knowledge base is the key index to judge the performance of the expert system, and the knowledge contained in the knowledge base reflects the thinking method of experts in related fields. For the intelligent alarm expert system of smart substations, the solution of specific problems needs to depend on the knowledge base. The main functions of the knowledge base include storage, retrieval and modification. One of the best ways to improve the expert system is to continuously improve and enrich the knowledge base.Therefore, if we want to establish a high-quality knowledge base, we need to be very familiar with the operation principle, operation method and troubleshooting method of the primary equipment, secondary equipment and relay protection equipment of the smart substation. The knowledge representation ways in the expert database include production and frame[2]. The production expression can be one or more premises, but the conclusion must be one. The resulting knowledge base structure is listed in Table 1.

Tab 1: Knowledge base structure of substation intelligent alarm

Name	Type	Cause	Handling scheme
Circuit breaker SF6 low alarm	Line-breaker	Circuit breaker SF6 pressure reduces to alarm pressure (sent by pressure relay)	Check the SF6 pressure on site, refer to the temperature and pressure curve, determine whether the pressure is too low, and report to the dispatching and the work area for timely handling

3) Inference scheme

Intelligent alarm system of smart substations needs to be realized by the inference engine technology. With the help of reasoning technology, specific fault causes and solutions can be inferred through the emergence of signals.

The realization of knowledge base function in expert system especially needs the inference engine. The intelligent alarm system of smart substations belongs to the production category. Its specific work flow is based on the information appearing on the site, and by comparing with the existing setting rules of the knowledge base, the best solution to the problem is obtained. The inference methods are usually divided into two types: forward inference and reverse inference. The alarm system of smart substations adopts forward inference and is divided into the following three categories.

① Single event inference

Since the types of alarm signals corresponding to each possible signal have been defined in the knowledge base of the expert system, it can be understood as the causal association formed by single event inference. This association relationship is defined manually according to field operation experience and stored in the database. When an alarm occurs in the smart substation, the inference machine matches the type of the alarm information with the data information stored in the knowledge base for processing. If the event conforms to the single event inference logic, it will deduce the cause of the exception and provide the solution to the problem. The single event inference model is shown in Figure3.

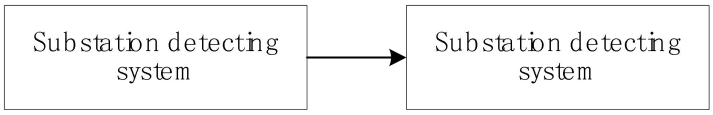

Fig 3: Single event inference model

There are many applications of single event inference, which are generally,alarms caused by a single cause. For example, if the protection device of a main transformer reports “zero sequence overvoltage on the low voltage side”, it can be inferred that the zero sequence voltage secondary loop is abnormal. The zero sequence overvoltage is not associated with other alarm signals and belongs to a single event.

② Associated multi-event inference

As the alarm information of smart substations in most cases has a certain correlation between each other, so it is necessary to consider and analyze the alarm information of these smart substation equipment, obtaining a solution, so that the cause of the fault can be more accurately judged, and a reasonable solution can be provided. This belongs to associated multi-event inference.

When multiple equipment of the smart substation has a variety of alarm information continuously in a short period of time, because of the internal correlation between these alarms, it is necessary to carry out a comprehensive analysis and conduct logical reasoning of these events, so to get a more comprehensive solution. For “multiple events”, the usual inferences methods include “enumeration method” and “inference method”.

The enumeration method is relatively simple, and the results are obtained by enumerating expert experience. The enumeration method has high alarm accuracy, and generally, it is only suitable for small-scale substations. As for the substations of 220 kV and above, due to the large scale andmultiple circuits, there will be a large workload when using theenumeration method workload, so it is inevitable to omit.

The inference method generally adopts the inference model, which has strong adaptability. It can be applied to the substations of various voltage levels and various sizes, and adapt to different equipment types. The multi-event inference model is manually programmed according to certain rules, and the inference process is composed of a series of multi-level logic loops such as and gate, or gate and nand gate. When the associated abnormal signal

satisfies the output of the inference model, the reasoning result is obtained. Figure 4 is a schematic diagram of the associated multi-event inference model.

The application of associatied multi-event inference is also widespread. For example, if a certain interval protection device reports “PT sampling anomaly” and a bus protection interval also reports “PT sampling anomaly”, it can be inferred that the merged unit is faulty. If a certain interval protection device reports “PT sampling anomaly” while a bus protection interval does not report “PT sampling anomaly”, it indicates that the merging unit does not fail, and it can be inferred that the interval protection device is faulty. Fig. 6 is a practical application of the correlation model, which inferences the line PT ontology fault.

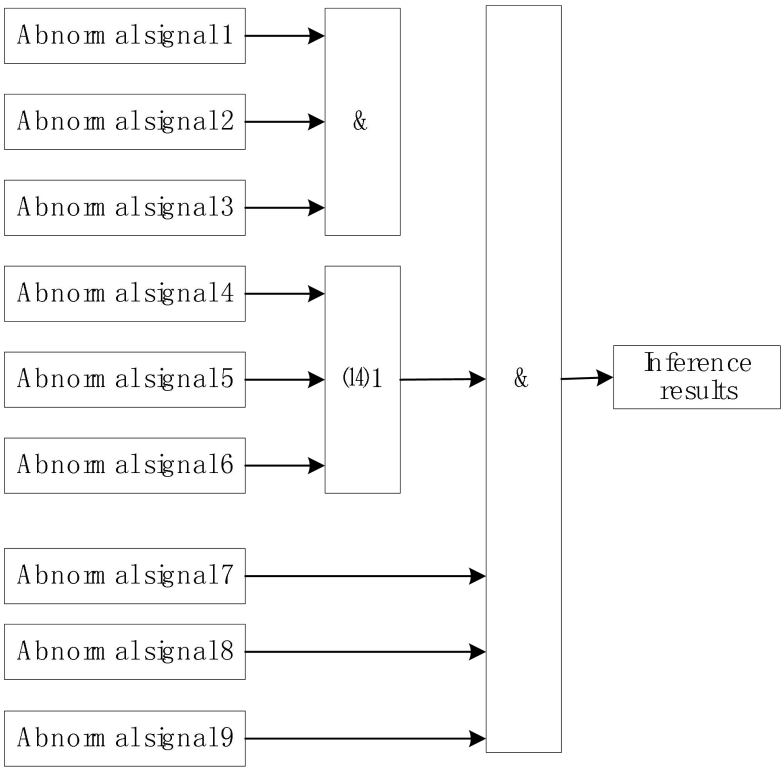

Fig 4: Schematic diagram of associated multi-event inference model

③ Fault intelligent inference

Fault intelligent inference methods mainly aim toimprove the operation and maintenance personnel’s fault handling level and reduce the maintenance workload of smart substation equipmentaccording to the critical conditions of intelligent substation faults, through comprehensively considering wiring methods, displacement information of switches, operational forms and remote measurement, etc., and special attention must be paid to the cause of the failure, the related information as well as the principles of failure handling.

In this paper, the semantic Web ontology concept was adopted to model the smart substation, and a reasonable fault identification rule base and knowledge base were designed on the C language integrated production system, so that the affected areas of various faults and the paths that might induce the occurrence of cascading faults could be searched among various devices, and the intelligent substation’s capability of fault identification and diagnosis could be improved, and corresponding treatment measures could be formulated. For example, if the main transformer and line protection MU protection are abnormal, the primary device fault can be inferred. If the switch

intelligent unit is abnormal, it can be inferred that the outlet hard press plate of the switch intelligent unit has a fault.

Figure 5 shows the logic diagram of inference engine for “line PT ontology fault” compiled by experts. The positioning logic used the concurrent voltage state of two sets of line protection and the concurrent state of measurement and control device, and deduced the results according to the combined action of outer-merging Unit (MU) of the line.

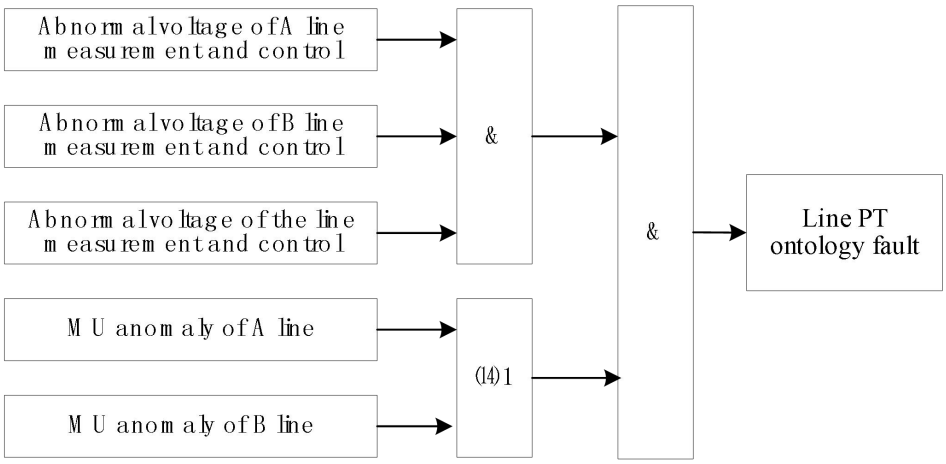

Fig 5: Line PT ontology fault reasoning

V. Conclusion

When the smart substation equipment has a fault, a large amount of information will appear in the monitoring system, so how to quickly understand the fault information and locate the fault has always been the concern of the operation and maintenance personnel. In this paper, the intelligent alarm technology and application were studied through alarm information classification, network topology analysis, information association and intelligent reasoning, and some achievements have been made. In the future, with the development of artificial intelligence and big data technology, intelligent alarm technology will make new breakthroughs, and the work in this aspect is also being carried out in an orderly way.

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