

Implementation of Grid Fault Diagnosis Expert System

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Abstract. Fault diagnosis expert system obtains the operation of power grid by monitoring the change of dynamic database. While all kinds of measurement, switching value and a part of status records and documents about the status of power grid operation transferred by fault information system and SCADA system are stored in the dynamic database. As the change of power grid operation state and the passage of time, we update the contents in the database. Once the failure and abnormality occur, the fault diagnosis expert system is started, so we can judge whether start core diagnostic program by starting detection. If the program starts, the whole diagnosis process should be under the unified dispatching. We can obtain the related information about the fault diagnosis continuously from dynamic database so as to form our own information chain and begin to carry out the reasoning. Finally, we make the diagnosis results be displayed to the dispatcher in a specified format so as to make the diagnosis results be as the reference of fault recovery processing.

Introduction

The fault diagnosis of power transmission network about the power system is a process of holding the result to find the reason and getting progressive refinement in general, so we can consider the layering properties and real-time requirements, and adopt the control strategy of the mixing chaining with the forward and backward chaining to judge the fault components according to the thought of “bold hypothesis, careful verification and laying diagnosis”.

Layering refers to that we make the fault diagnosis be divided into several steps.

(1) We first judge the fault zone from the switch alarm information. Because we can guarantee that we can obtain the switch change information fast and reliably in any SCADA system and the obtained information is generally more accurate, using the switch change information we can get a rapid positioning of the electrical equipment with simple fault or find fault zone, what's more, we can not miss any fault equipment.

(2) For the blackout area with the occurrence of complex faults, the fault equipment which is judged to get based on the switch information may not be the only one, so we can make use of protection action information to narrow the scope of possible failure further on the basis. In this way we can determine the fault components specially.

(3) If at this time we can't locate the fault components, we will get an active query of the information about the fault recorder. And after that we can analyze it. We adopt the control strategy of the mixing chaining with the forward and backward chaining. Among them, the forward chaining is driven by real-time fault data. We adopt the laying method to make a preliminary judgment about the fault reason and make them be in order according to the size of fault credibility. Then for the assumed fault components we drive backward chaining process to validate with expert rules, and rule out the fault components to determine the fault components, and finally we get the cause of the power grid failure and the evaluation of secondary equipment action situation.

The Starting Detection of Core Diagnostic Program

This core fault diagnosis system is in a dormant state when the power grid is in the state of normal operation. Only after the failure of the system occurs, we can make the judgment and the reasoning. Under the condition of normal operation, if we make the normal switching operation, the switch displacement may be caused. It is not the fault action. But it also serves as an alarm message in the SCADA system for us to process. Our fault diagnosis program should be able to detect similar switch displacement without the failure. The process is the starting detection of fault diagnosis, that is to say, it is also the re-detecting process of alarm information.

The Diagnosis Process Based on the Switch Information

The Judgment of the Direction with Components and Switches. Each component in a power system includes bus bar, line and transformer. According to the possible trend direction, we can divide them into double end components and single end components. So is the circuit breaker. It can be divided into two-way switch and unidirectional switch. In power transmission network, not all the faults can be defined by trip switch, for example, load line side fault can only have the side switch trip of the power, at that time the line is one-way power line, and the switch on both ends of the line is one-way power switch. In the fault diagnosis should be able to distinguish between one-way power switch and bi-directional power switch, or else we will not be able to determine which switches are the mis-reported switches, and which switches are normal switches without the action. According to the direction of the switch, in the process of fault zone search, we can reduce the unnecessary search and speed up the search speed.

The Steps of Dividing the Fault Zone. Based on the fault zones demarcated by the trip switch we begin from some trip switch we make the depth-first search in the direction of switch protection and within the scope of protection. Among them switch protection range is demarcated according to the scope of acting switch protection with its maximum range. Because when the failure of the actual system occurs, the skip-level of protective action caused by the switch or protective action resistance is generally not more than two levels, and the search depth is not more than two levels at most.

According to the direction of the switch, the search principle can be seen as follows.

(1) If the property of a particular trip switch is bi-directional switch, both sides should be searched.

(2) If the property of the particular trip switch is one-way switch, we can only search in the direction of switch protection, and record this path.

(3) If the equipment on each search path is assumed fault equipment, we can deposit the collection of assumed fault equipment.

The Intersecting Rules of Protection Scope. When multiple faults or complicated faults caused by the switch and protective action resistance occur in different locations, we should enable multiple protections correspond to protection actions with different protection scopes. When we take the intersection for the scope of protection, in order to make the fault zone by the diagnose as small as possible, we need to consider different types of protection, that is to say, the protection with certainty and uncertainty make contributions to the fault diagnosis results. Therefore, we need to determine the rules of getting the intersection for a set of protection scope. First we make the action protection be classified to get the fault zone by the judgment according to switch.

(1) The Division of Action protection. The obtained action protection zone and fault zone segmented by the blackout area should be classified correspond. If a fault area includes one or a few components within the scope of protection about a protection, then the protection belongs to the relevant protection in the fault area.

(2) The Crossing Rule. We use $F(X)$ to represent the protection range of taking the protection X . X_q represents the protection X is the deterministic protection. X_b represents the protection X is the non-deterministic protection. Actas (F) represents that we make the protection range F as the fault

zone or the fault component. If there is no the fault zone or the fault component in the collection of fault results, we will make it be stored in the collection. Reserve(F) represents that for the protection range F we can't be sure that it is the fault zone or the fault component in the process of reasoning. We should make it be as a temporary fault diagnosis result. If the fault diagnosis finishes, and no other information deny that it is not the fault zone or fault component, we can make it be as the final diagnosis and add it to the collection of fault results.

Thus, the rule of taking intersection about the protection range can be represented as a series of formulas as follows with the symbols mentioned above.

$$\begin{aligned} & \text{if } F(I_q) \cap F(J_q) \neq \emptyset \\ & \text{then } Actas(F(I_q)) \cup Actas(F(J_q)) \end{aligned} \quad (1)$$

The formula (1) represents that when the corresponding fault components of two deterministic protections have the same part, because the deterministic protection only corresponds to the only fault component, their corresponding fault components must be the same. For example, for the grounding distance protection with the same line and Phase spacing protection action, their protection ranges all correspond to this line, thus we determine that the line has fault.

$$\begin{aligned} & \text{if } F(I_q) \cap F(J_q) = \emptyset \\ & \text{then } Actas(F(I_q) \cup F(J_q)) \end{aligned} \quad (2)$$

The formula (2) refers to when the failure of two and more sites occur at the same time, for the deterministic protection action at the fault point, because the deterministic protection only corresponds to the only fault component, the corresponding protection range of the deterministic protections at different fault points will never meet. But they are fault components. For example, 330KV1# busbar protection and 110 kv some line protection action, 330KV1# bus and 110 kv line all can be as fault component.

$$\begin{aligned} & \text{if } F(I_q) \cap F(J_b) \neq \emptyset \\ & \text{then } Actas(F(I_q)) \end{aligned} \quad (3)$$

The formula (3) represents that when the corresponding protection ranges of the deterministic protections intersect the corresponding protection ranges of the non-deterministic protections, we can take the corresponding protection ranges of the deterministic protections as the fault point. For example, the reasoning results of intersecting about 10KV line fault, the switch action resistance, overcurrent and quick break protection action of this line, the backup protection action at the side of the main transformer 10KV, the corresponding 10 KV line of overcurrent and quick break protection, the corresponding 10 KV system at the side of the main transformer 10KV should take the 10 KV line as a fault component.

$$\begin{aligned} & \text{if } F(I_q) \cap F(J_b) \neq \emptyset \\ & \text{then } Actas(F(I_q) \cup Reserve(F(J_b))) \end{aligned} \quad (4)$$

The formula (4) represents that when the corresponding protection ranges of the deterministic protections don't intersect the corresponding protection ranges of the non-deterministic protections, we can not only take the corresponding protection ranges of the deterministic protections as the fault point, but also keep the corresponding protection ranges of the non-deterministic protections as suspicious fault point. For example, when the failure occurs on two or more sites and the main protection doesn't move in one of the site, for the backup protection action, the backup protection range doesn't intersect the main protection range in other sites. Therefore, we need to keep the corresponding protection range of this backup as suspicious fault point.

$$\begin{aligned} & \text{if } F(I_b) \cap F(J_b) \neq \emptyset \\ & \text{then } Reserve(F(I_b) \cap F(J_b)) \end{aligned} \quad (5)$$

The formula (5) represents that when the corresponding protection ranges of the non-deterministic protections intersect, we can keep their own corresponding protection ranges as suspicious fault points.

$$\begin{aligned} & \text{if } F(I_b) \cap F(J_b) = \emptyset \\ & \text{then } \text{Re.serve}(F(I_b) \cap F(J_b)) \end{aligned} \quad (6)$$

The formula (5) represents that when the corresponding protection ranges of the non-deterministic protections don't intersect, we can keep their own corresponding protection ranges as suspicious fault points.

Conclusion

We introduce the concrete implementation method of fault diagnosis expert system in details in this paper. By the thought of making full use of all kinds of fault information we adopt the control strategy of the mixing chaining with the forward and backward chaining to judge the fault components by layers. In order to achieve fast and efficient diagnosis software, we use some treatment measures.

(1) Because the distribution of power source directly affects the diagnosis result, we need to judge whether the both sides of the switch have the power source or not. Each time the power grid structure changes, all we should do is to search again. Even though the search volume of the process is big, they are done offline, so it does not affect the diagnosis speed.

(2) Because the protection configuration of power system and the setting situation are quite complicated, protection range of the protection has changed a lot the different power grid operations. If we determine that the protection range needs complex calculation in detail, it is difficult to achieve real-time requirements. Therefore, we assume to use simplified method, make full use of the object-oriented knowledge to represent the advantages, and search to determine the protection range. When we do the fault diagnosis, we only search a few action protection. And the search time accounts for only a small part of the whole diagnosis process.

(3) In the process of backward reasoning we adopt simple and intuitive conflict resolution strategy to speed up the matching verification with expert rules. Finally, according to the requirements of the functional design, we give diagnosis result and show display.

References

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