Research on Active Distribution Network Monitoring and Police Method of Substation Based on Fault Tree

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Abstract. Substation is a power facility for transforming voltage, receiving and distributing power, controlling power flow and adjusting voltage in power system. After the active distribution network fails, it can effectively improve the power supply reliability of the distribution network by comprehensively utilizing the islanding operation ability of the standby contact line and the internal DG to restore the power supply for the outage load after the failure. Considering the main transformer fault and the timing characteristics of the DG output, the fault point is located in the shorter section between the intelligent bodies through the initial fault location. The fault secondary point is used to determine the fault point and the switch on both sides of the fault point is disconnected. Isolating the fault zone and restoring the power supply of the non-faulty section. It is an important technical measure to ensure that the voltage of each node in the power grid meets the required constraints, accurately locate the fault point, and ensure the reliable operation of the power grid.

1. Introduction
In recent years, distributed power sources, such as wind power, photovoltaic, energy storage power stations, micro-gas turbines, have attracted wide attention due to their clean, efficient and renewable characteristics, as an effective complement to centralized power generation [1]. Because of the double uncertainties of power supply and load in active distribution network, the traditional distribution network protection based on current protection can not quickly and accurately isolate the fault section [2]. Channel-based distributed fault processing uses FTU mutual communication, protection cooperation and timing cooperation to complete fault processing, also known as surface-based protection or intelligent distributed [3]. The current voltage control of the transmission network is relatively mature, and the voltage control of the distribution network usually only goes to the low-voltage bus of the substation. The control equipment is regulated by the on-load transformer tap and the parallel reactive compensation capacitor [4]. In the design of the island protection scheme, it is necessary to analyze the changes in the electrical quantity and frequency of the voltage before and after the island in the system. The control strategy used by the synchronous generator system and the grid-connected inverter system is different. It is feasible to consider the substation planning scheme of distributed power supply, make full use of the capacity value of distributed power supply, coordinate the supply load of distributed power supply and new substation, and the relationship between location and volume is the focus of future research [5].

Because of its flexible power regulation and AC/DC conversion functions, it can not only conveniently access distributed energy sources, electric vehicle batteries and other bidirectional load and energy storage devices, but also conveniently control the operation mode of distribution network [6]. The reliability standard in the power supply range of substation is usually chosen as the reliability index of the system before the distributed power supply is added; CCPV (i) is the confidence capacity
of all photovoltaic power sources in the power supply range of the first substation; CCWTG (i) is the confidence capacity of all fan power sources in the power supply range of the second substation [7]. Because voltage relays can provide overvoltage protection for distributed generation devices, voltage relays are usually installed in distributed generation systems [8]. In this way, voltage relay and frequency relay can be used for island protection without increasing cost [9]. In the case where the conventional voltage control method is ineffective, the method of reducing the active output of the DG is used to restore the over-limit node voltage to normal. It realizes direct control of active and reactive power of DG, which can meet the access point voltage and line heat capacity limit. In this paper, the monitoring method of substation active distribution network monitoring and alarming for fault tree is studied [10].

2. Materials And Methods

2.1. Parameters for Reliability Analysis of Distribution Network

Making full use of DG's power generation capacity and maximizing the restoration of blackout load is an important research content of intelligent distribution network, which can effectively improve the initiative of distribution network operation and disaster resistance. Ensuring the normal operation of DER in non-fault section can effectively improve the reliability of power supply in non-fault section. Moreover, only the judgement result of Agent is transmitted on the network, which can lighten the burden of the network and locate the fault point quickly. With the access of DG, the distribution network will become an active network with bidirectional current flow. Therefore, directional elements should be installed on the basis of overcurrent protection. In addition, when the system fails, the magnitude and direction of the fault current will change due to the augmentation of DG. Different types of loads have different load characteristic curves and different peak and valley times. If only the total load analysis is limited, the load changes of different industries are ignored. The optimal value of the decision is fed back to the second stage, and then the second stage chooses the decision which makes the global benefit optimal according to the optimal value of the first stage feedback. Accordingly, the objective function can be divided into two stages for processing. Starting from the top event of the fault tree, if the top event is an OR gate, each input event is respectively listed in a different row; if the top event is an AND gate, each input event is included in the same row. It should be noted that the over-voltage and over-under-frequency protection adopted by the grid-connected inverter does not refer to the actual relay, but is implemented based on software. Therefore, the use of existing overvoltage and underfrequency protection in grid-connected inverters is a low-cost option for island protection.

The reliability of distribution network can be calculated according to the reliability parameters of the underlying components. The parameters for reliability analysis of distribution network are shown in Table 1.

| Parameter       | Bus bar | line | Dry type transformer | Commutation equipment | High frequency transformer |
|-----------------|---------|------|----------------------|----------------------|--------------------------|
| Failure rate    | 0.3     | 0.5  | 0.005                | 0.524                | 0.004                    |
| Failure Repair  | 2       | 4    | 100                  | 16                   | 100                      |

2.2. Fault Location to Determine Fault Points

Fault tree is to take the most undesirable fault state as the goal of fault analysis and find out all possible direct causes and factors leading to this event. The fault location determines the fault point and isolates the fault section, so as to quickly restore the power supply in the non-fault section. Compared with the existing protection schemes, the scheme is simple in principle and can selectively isolate the fault section completely without configuring directional elements. When the high permeability distributed generation is connected to the distribution network, its output can supply part of the load, so the load rate of substation can not actually represent the relationship between the output of substation and the load in the supply area. Reducing fault current is beneficial to the original intention of automatic arc extinguishing, and increases the degree of damage to fault points. Especially for cable faults which may
lead to more serious two-phase short circuit faults, EMC environment will also be damaged to a certain extent, and step voltage may also be generated when the increase current is large. The output of DG is a continuous variable, and the transformer gear and capacitor switching are discrete variables, and the control results between adjacent time periods affect each other. Therefore, this is a hybrid planning problem for a multi-stage decision making process. Low voltage and zero sequence voltage start-up components can be added to increase the sensitivity of the protection. In addition, the low voltage protection action element and the over voltage protection action element can be added to improve the reliability of the protection. The control mode DG is also included in the consideration of power restoration decision-making, and is called ordinary DG. Although it cannot be operated by independent islands, in the case of a main power supply with V/f control mode nearby, this type of DG Follow the main power supply and connect to the grid to recover more load.

According to the actual situation of distribution network, different scenarios of transformer baffle and capacitor group switching in different time periods are combined and allocated to the first stage. The first stage carries out local optimization in parallel according to the combined results of allocation. In carrier-locked islanding protection, fault or transient disturbance may also affect the transmission of carrier signals, so voltage and frequency protection still needs to maintain the traditional protection. Local current information can be collected and analyzed, and the analysis results can be peer-to-peer exchanged between Ethernet and adjacent agents to determine the location of fault points. According to the number of branches of nodes (DER lines are also considered as a branch), the nodes are divided into two branches and multi-branches. As long as the capacity of transformer and line is within the range, the power supply can generally be stable and continuous. However, based on the DG island operation to restore power supply, we must fully consider the island's sustainable and stable operation capability, which is based on the nature of the power grid and DG to restore power.

According to the reasons and accumulated experience of substation overhaul electric shock accident, taking substation overhaul electric shock accident as the top event, the top event and each intermediate event are analyzed. The model of electric shock fault tree for substation maintenance personnel is shown in Figure 1.

![Electric Shock Fault Tree Model for Substation Maintenance Personnel](image)
3. Result Analysis and Discussion

3.1. Distribution Characteristics of Fault Current

From the fault tree analysis of substation overhaul, it can be seen that the operator's error interval and wrong boarding of equipment are the main reasons for the occurrence of electric shock accidents, and key control should be carried out. Isolate the fault section. Because the circuit breaker adjacent to the load switch is disconnected, the power failure in the adjacent non-fault section is caused. Therefore, the circuit breaker should be connected with the relay protection to restore the power supply in the non-fault section. Carrier blocking islanding protection also has obvious resistance to interference caused by signal generator failure. This is conducive to the application of carrier signal in islanding detection, and greatly enhances the practicability of carrier locked islanding protection. When there is a bad scenario combination, the bad scenario information is fed back to the second stage, and the combination is deleted in the second stage when the global optimization is carried out. It has the advantage of flexible access during operation, but considering the comparability, when comparing the two, the PV station in the distribution network of the traditional station adopts the method of variable current and post-boost, and its power supply path and the substations are basically the same. Each island agent can perform its own functions and process in parallel, which makes the fault handling method more flexible and fast. At the same time, through the interactivity between agents, the global problem can be unified and coordinated, and the global optimal power restoration scheme can be obtained.

The current of the branch is the largest by comparison, so among the three branches of the same node, the current of the fault branch is the largest. The current analysis of the branch of the node is shown in Table 2 and Figure 2.

| Load                        | Node |
|-----------------------------|------|
| Fault point adjacent        | 0.65 | 0.73 |
| Short circuit current magnitude | 0.59 | 0.63 |

**Table 2. Node branch current**

![Fig.2. Node branch current](image-url)
3.2. **DG Equivalence of Standby Contact Lines in Active Distribution Network**

In order to ensure the reliability of power supply in distribution network, some standby lines or feeders are usually laid in the process of construction of distribution network, which can be used as standby lines to realize the transfer of blackout load in case of faults. According to the distribution characteristics of fault current in active distribution network, substation faults include high voltage, low voltage side converter faults and high frequency transformer faults. According to the main wiring scheme, various operation modes of power electronic substation are considered, from result to cause analysis. A distributed intelligent current protection scheme is proposed. The scheme consists of two steps: primary fault location and secondary fault location. Then, the effectiveness of carrier locked islanding protection scheme is evaluated theoretically. Because the voltage and frequency of grid-connected inverters will stabilize to a certain value after islanding operation, the grid-connected inverters system is analyzed. The maximum value of the load is simply superimposed with the distributed power output, and the distributed power supply confidence capacity can be obtained according to the characteristic curve of the load and the time series output curve of the distributed power supply. When the tie switches are disconnected, the system is a conventional radial distribution network. When it is detected that the tie switch is closed in the system, the system operates as a weak loop. Through the minimum path set of the fault tree, it can be analyzed that the prevention of substation maintenance and electric shock accidents should first control the personnel to go wrong, miss the equipment, and prevent high-voltage electric shock.

For substations, depending on the use of high-voltage, low-voltage converters and high-frequency transformer ports in power supply paths, their reliability parameters are regarded as corresponding converters and series connection. There is no fence at the pressurizing end, no warning board at the other end and no guard. When measuring insulation resistance on the line with induction voltage, no power cut measures are taken. Loop current in loop network leads to further increase of network loss. On the contrary, the generation of loop current makes the distribution of node voltage more balanced. When there is only commercial load in the power supply range of substation, the confidence of distributed generation is larger; when there is only residential load in the power supply range of substation, the confidence of distributed generation is smaller. Undervoltage protection will operate first. If the neutral phase non-effective grounding system has a single phase ground fault, the island protection will delay the action after the busbar protection action. Locate a segment that locates a fault point between two adjacent nodes of a shorter fault section. The related agent issues a command to the protection, disconnects the switches on both sides of the fault point, isolates the faulty section, and quickly restores the power of the non-faulty section. After the DG is integrated into the distribution network, it is necessary to comprehensively consider the two types of resources, the standby line and the DG, for global comprehensive optimization. However, the standby line and the DG have completely different working modes, operating characteristics, mathematical models, and the like.

4. **Conclusion**

In this paper, the method of monitoring and alarming police of active distribution network in Substation Based on fault tree is studied. Reasonable change of system topology can be used as one of the means to solve the problem of over-voltage caused by DG access in active distribution network. The influence of load characteristics of different types of loads on the confidence capacity evaluation of distributed power supply is realized, and the objective evaluation of the capacity value of distributed power supply is realized. Based on over-voltage protection and over-under-frequency protection, adding carrier blocking measures can greatly improve the sensitivity and reliability of protection, reduce the measure of detecting the carrier signal of bus islands in blind area, and avoid the protection rejection when bus islands. In order to improve the reliability of distribution network, the internal DG can not be all random uncontrollable power supply, and a certain number of controllable DG should be allocated as the main power supply to improve the islanding operation ability of distribution network. At the same time, according to the application of new equipment and new technology, the advanced safety analysis method should be used in time for analysis and research, and the accident prevention and control measures
should be determined based on the actual situation on site. Meet the power supply reliability requirements of non-faulty users. The principle of the scheme is simple, and it has certain theoretical guiding significance for solving the protection problem caused by the distributed power supply to the distribution network.

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