Application of 66kV Active Intervention Grounding Arc Suppression Device

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Abstract—The energy supply is mainly based on electric energy at present, and power supply reliability is an important indicator for evaluating power supply services. In view of the 66kV transmission voltage level unique to Northeast my country, the neutral point of the transmission system directly affects the stable operation of the power system. First, the composition of the substation in the system and the working principle of the arc suppression device are analyzed. Secondly, when a single-phase grounding fault occurs in a 66kV neutral point ungrounded system, an active intervention grounding arc suppression device is designed. Finally, the operating characteristics of the designed grounding arc suppression device are demonstrated based on the simulation results.

1. Introduction
The electric energy generation and consumption system consisting of power generation, transmission, transformation, distribution and power consumption is called the power system. Its function is to convert the primary energy in nature into electrical energy through power generation devices, and then supply electrical energy to the user through power transmission, transformation and distribution[1]. In order to improve transmission efficiency and reduce route loss, power plants must increase the voltage to high-voltage power when transmitting electric energy to farther places, and then reduce the voltage according to the demand near the user. This buck-boost work depends on The substation is a power facility that transforms voltage, receives and distributes electrical energy, controls the flow of power, and adjusts the voltage in the power system[2], [3]. It connects the power grids of various voltages through its transformers. Therefore, the substation plays a very important role in the power system[4].

The normal operation of the substation requires the coordination of various equipment. According to the division of labor, these equipment can be divided into primary equipment and secondary equipment[5]. The primary equipment mainly includes transformers, transformers, switchgear, lightning protection equipment[6]. The secondary equipment mainly includes some signal acquisition devices, control devices, communication devices. The division of labor between primary and secondary equipment is different, but there is a certain connection between them[7]. For example, primary equipment provides secondary equipment with physical quantities that need to be collected.

2. Design of 66kV Active Intervention Grounding Arc Suppression Device

2.1. Constitution and principle of arc suppression device
The complete set of equipment takes the grounding protection device as the core, real-time data collection, calculation of the bus voltage where the device is installed, and changes in phase, line
voltage, zero sequence voltage and ground current to identify whether the system is grounded or not. If a phase of the system is grounded, the grounding protection device will accurately and quickly issue the corresponding phase-separated switch closing instruction. After the switch is closed, 100% of the grounding phase is connected to the grounding grid, so that the grounding phase and the earth are forced to wait. Potential, transfer the ground current at the ground fault point, so that the current at the ground fault point tends to zero, and the arc can not be maintained and extinguished, which will cause a short circuit and overvoltage caused by the human body, the internal grounding of the equipment, and the ground fault.

The complete set of equipment is composed of main components such as phase-separated grounding switch, isolating switch, zero-sequence current transformer, low excitation impedance transformer, and a central control system composed of grounding protection control device, grounding line selection device, and drive locking unit.

From the point of view of the connection mode of the device, one end of the complete set of device is connected to the 66kV bus of the substation, and one end is connected to the grounding grid of the substation. Among them, the grounding protection device and grounding line selection device are control, protection and automation devices specially developed by us for the complete set of separate-phase automatic direct grounding protection devices. The split-phase operation switch used is a 66kV single-phase sulfur hexafluoride switch. The lower mouth of each switch is sealed to ground. It controls the on-off of the single-phase switch by the level. The complete set of devices can respectively achieve 100% grounding requirements.

\[
\frac{U_a + U_0}{-jX_c} + \frac{U_b + U_0}{-jX_c} + \frac{U_c + U_0}{-jX_c} + \frac{U_a + U_0}{R_g} = 0
\] (1)

Fig.1 Neutral point grounding three-phase schematic diagram

Fig.2 Neutral point grounded three-phase equivalent circuit diagram

The following two equations can be drawn from the figure 1 and figure 2:
2.2. Realization of grounding arc suppression device

The grounding protection device monitors the operating conditions of the substation in real time, collects the bus voltage and zero sequence voltage on the 66kV side, and calculates the amplitude and angle of the zero sequence voltage in real time. Determine whether there is a single-phase ground fault based on the calculated value. If the single-phase grounding fault conditions are met, the corresponding phase-specific single-phase circuit breaker close command is issued and the wave is recorded. In addition, the grounding protection device has a blocking function for non-single-phase grounding faults such as PT disconnection, ferromagnetic resonance, one-phase or two-phase disconnection of the system, and grounding when the same name is the same.

Single-phase grounding faults can be divided into: steady-state grounding, instantaneous grounding and intermittent grounding from the grounding time; from the nature of grounding, it can be divided into: metallic grounding and high-resistance grounding. The grounding characteristics of each grounding form are different, and the zero sequence voltage reflected is also different. The steady-state grounding lasts for a long time, and the zero-sequence voltage is relatively stable; most single-phase grounding is instantaneous grounding, which can generally recover by itself. The duration is within 40ms and the zero-sequence voltage changes greatly. Intermittent grounding is more harmful and it is a process of repeated breakdown recovery. As the non-grounded phase voltage rises, it is likely to cause insulation breakdown and inter-phase short-circuit accidents. Its zero sequence voltage is a non-sinusoidal function. The zero sequence voltage of metallic grounding is stable and the amplitude is high; the zero sequence voltage amplitude of high resistance grounding is low.

The working principle of the 66kV active intervention grounding arc suppression device is to directly connect the grounding phase to the ground grid. If the phase difference is judged incorrectly, it will cause a phase-to-phase short circuit fault, and the consequences will be very serious. Therefore, the accuracy of the grounding phase judgment is particularly important. At the same time, in order to protect the human body from electric induction, the electric induction time is shortened as much as possible, and the device is required to have a fast start-up speed, and the sensitivity of its judgment is also very important.

The ground fault judgment is mainly based on the zero-sequence voltage, and we use the magnitude and phase change of the zero-sequence voltage mutation as the judgment conditions. There will be a certain zero-sequence voltage during normal operation of the system. When single-phase grounding occurs, the zero-sequence voltage will change in amplitude and phase. Figure 3 is the waveform diagram of the three-phase voltage and zero-sequence voltage when the system is operating normally.
It can be seen from figure 3 that the system is balanced. When there is no single-phase ground fault, the three-phase voltages are equal and the zero sequence voltage is zero.

The grounding line selection of a small ground current system has been a relatively difficult problem to solve due to factors such as small signal amplitude and insignificant zero-sequence current changes. Active intervention type grounding transfer device in the case of a single-phase grounding fault occurs, the device operates within 50ms, and the line selection device must have the performance of synchronous and quick start.

We use high-speed signal processor DSP, multi-channel synchronous sampling, the sampling speed reaches 640 times/cycle, and synchronous sampling of the zero sequence current and system zero sequence voltage of each circuit before and after the split-phase circuit breaker is activated to ensure the synchronization of each signal. Using the unique feature of the split-phase automatic direct grounding protection device before and after the action, the zero sequence current of the fault loop will change, and the line selection can accurately select the fault ground loop.

When single-phase grounding occurs, as the degree of grounding becomes heavier, the ground loop impedance shows a downward trend, while the non-fault loop impedance rises. After the grounding protection, the grounding loop presents the characteristic of a sudden rise, and each line is restored to the maximum impedance.

In the device design, the zero sequence impedance of each line before grounding protection is first calculated, and the line whose zero sequence impedance shows a downward trend or the smallest change is used as the preselected line, and then the zero sequence impedance of the preselected line after the grounding protection is calculated. The largest change ratio is determined as Ground loop.

Low ground current system grounding line selection has always been a relatively difficult problem, especially for high-resistance grounding, the zero-sequence current change characteristics are not obvious, and the current line selection methods can not accurately select the ground loop. Since this device will transfer the ground current by operating the single-phase circuit breaker after the ground fault occurs, the zero sequence current of the ground loop will have obvious changes. Therefore, we design the line selection method according to this principle, which can greatly improve the line selection and the accuracy rate.

3. Simulation Results of 66kV Active Intervention Arc Suppression Device

The figure 4 shows the three-phase voltage and zero-sequence voltage waveform after the occurrence of a single-phase ground fault and the three-phase voltage and zero-sequence voltage waveform after the action of the active intervention type grounding arc suppression device.
Fig. 4 The waveform diagram before and after device operation

It can be seen from the figure 4 that the system was operating normally before 1.5 seconds, the three-phase voltages were equal, and there was no zero-sequence voltage. A single-phase ground fault occurred at 1.5 seconds. At this time, the ground phase voltage is pulled down, and the normal phase voltage rises, resulting in a zero sequence voltage. At 2.0 seconds, when the device operates, the phase A voltage of the grounding phase is forced to be equal to the ground potential and becomes a 100% metallic steady-state grounding. The grounding current is as shown in the figure 5.

Fig. 5 Loading scene of specimens

It can be seen from the figure 5 that when the system is operating normally, there is no capacitive current flowing through each line. When a single-phase grounding occurs, each feeder line generates a capacitive current. After the grounding device operates, the capacitance current of each line increases due to the decrease of the ground impedance, and the largest amount of change is the grounding line. In the figure 4, $I_1$ has the largest amount of change, so it can be defined that $I_1$ is the current of the grounding circuit.

4. Conclusion

The design of the grounding protection device adopts the zero sequence voltage displacement and phase voltage slope change to improve the accuracy and sensitivity of the phase selection judgment; according to the zero sequence direction change before and after the protection action, the zero sequence impedance change and the difference line selection method, the fault circuit is determined, thereby improving the accuracy of line selection. The circuit breaker is closed when the voltage difference is equal to zero and opened when the passing current crosses zero, so that when the grounding protection device is put into and out of the system, the additional change of the system's
The ground voltage is reduced and the additional excessive process is generated. The use of advanced power electronic technology integrates grounding phase selection, line selection and protection functions, innovating the power system split-phase automatic grounding method and the method of using transfer current to extinguish the grounding point arc. It is an ideal grounding protection for low-current grounding system devices.

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