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Research on grid voltage suppression and current limiting protection

Yan Chuang, Jiang Li

State Grid Liaoning Electric Power CO,LTD. Power Electric Research Institute, Shenyang, Liaoning110015, China

ABSTRACT. *Over-voltage such as operation, interception, resonance and lightning strike of power system threaten the safe operation of electrical equipment insulation and power system. Especially, single-phase intermittent arc grounding overvoltage is the most serious when intermittent arcing occurs. When grounding, due to the repeated intermittent arcing and repeated re-ignition, the high-frequency oscillation overvoltage will be caused in the faulty and non-faulty phase of the inductor-capacitor loop, and the overvoltage amplitude of the non-fault phase is generally reachable. 3.15-3.5 times the phase voltage, often due to single-phase grounding and then become multi-phase grounding, and the large-scale power outage of the power system caused by the accident caused by the accidental expansion.*

KEYWORDS: *grid voltage; protection research*

1. Introduction

At present, the arcing coil is used to solve the arc grounding faults. The inductor current generated by the arc suppression coil itself is used to compensate the grounding capacitor current of the grid, and the grounding current of the fault point is reduced, so that the grounding arc of the residual current is easily extinguished. When the arc is extinguished when the current crosses zero, the rising speed of the fault phase recovery voltage can be reduced to avoid arc reignition; in addition, the arc suppression coil can also reduce the amplitude of the single-phase grounding overvoltage, thereby limiting the damage of the ground fault. Improve the reliability of power grid supply. However, with the expansion of the distribution network and the increase of various types of loads in the power grid, the arc-extinguishing effect of the arc suppression coil has been seriously affected [1-2]. This is mainly because the expansion of the distribution network and the increase of cable lines have led to a sharp increase in the capacitance current of the system to the ground. The capacity of the arc suppression coil can no longer meet the compensation requirements; at the same time, the arc suppression coil cannot compensate for the higher harmonic components in the ground current. However, the input of a large number of

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converter equipment and non-linear load in the current medium voltage distribution network increases the harmonic content in the power grid, affecting the compensation of the grounding current of the arc suppression coil; and because all the current arc suppression coils are designed The automatic tracking compensation devices are all operated at the power frequency of the power grid (50 Hz). Under the high frequency oscillation overvoltage caused by the intermittent arc, the frequency characteristics of the arc suppression coil and the grid capacitance are very different, and it is impossible to compensate each other or Tuning; and the arc suppression coil is a reactive power compensation device that does not compensate for the active component of the ground current. Therefore, in some distribution networks, especially in the distribution network of cement, metallurgy, petrochemical, and coal industries where the system has a large capacitance current and complex content, after the single-phase ground fault occurs, the arc suppression coil is put into operation. Compensation, there may still be a large residual flow in the system, which is not conducive to the extinction of the arc.

Since the introduction and use of zinc oxide varistor tablets, their rapid development has been remarkable, characterized by good nonlinear characteristics and large energy capacity (surge absorption capacity), high-energy nonlinear damping. The material, namely high-energy zinc oxide varistor, has also been rapidly developed in the past decade, and has been applied to surge absorption and over-voltage protection of various large energies, and has broad application prospects. However, in the practical application process, the zinc oxide varistor chip needs to consider its charging rate, so that its threshold voltage will be taken higher, so that when it is used, it will not be effective overvoltage when it encounters a large energy operating overvoltage. Protective effects.

This project is aimed at the actual problems of various overvoltages in the power grid, combined with the advantages and disadvantages of zinc oxide varistor materials, and the research and product development of grid overvoltage suppression and current limiting protection devices based on high energy nonlinear damping materials. Work can effectively solve many types of overvoltage problems, which has important economic and practical significance [3-4].

The energy at the time of overvoltage is completely absorbed, and the oscillation of energy is suppressed from the source to achieve effective damping of various overvoltages of phase-phase and phase-ground, and weak insulation of generators, power transformers, high-voltage motors, etc. in the power system. The equipment can fully play a positive protective role and improve the safety and reliability of the power grid. After the application of the results, it can effectively suppress the phase-phase, phase-to-earth resonance and operating overvoltage of the power grid, and realize a new type of topology adding device to solve various types of over-voltage problems, thereby improving the safety and reliability of the power supply of the power grid. Compared with the traditional over-voltage suppression and current-limit protection, it eliminates all kinds of over-voltage from the source-topology-device level innovation from the source, and has the function of solving the problem of multi-type over-voltage, and the appearance and size of the project results. The design of insulation, sealing and so on can adapt to the actual

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operating environment and has good adaptability. Therefore, it will be concerned by people, showing potential important value in the field of overvoltage suppression and current limiting protection, and has a good promotion prospect. It is promoted and applied in the technical transformation or overhaul of the power grid, which plays an effective over-voltage protection role for various key equipments in the power system, and has great application prospects in the protection of power grid equipment. The power grid safety hazard caused by overvoltage is reduced, and the reliability and safety of power supply are improved, and the direct benefit is remarkable. Improve the safety production management level of power grid operation, effectively ensure the safe and stable operation of the power grid, improve the reliability of power supply, reduce power outages caused by overvoltage and even more serious safety accidents, and have inestimable indirect economic benefits and far-reaching social benefits [5]

2. Summary of research level at home and abroad

Power system operation, interception, resonance and lightning strikes are threatening the safety of electrical equipment and the safe operation of power systems. Especially, single-phase intermittent arc grounding overvoltage is the most serious. When intermittent arc grounding occurs. Due to the repeated extinguishing and re-ignition of the unstable intermittent arc, the high-frequency oscillation overvoltage will be caused on the inductor-capacitor loop of the fault phase and the non-fault phase, and the overvoltage amplitude of the non-fault phase is generally up to 3.15- 3.5 times the phase voltage, often due to single-phase grounding and then become multi-phase grounding, and the large-scale power outage of the power system caused by the accident caused by the accidental expansion. A lot of operating experience shows that in the case of single-phase arc grounding, the system can only run for a few seconds for a few minutes, which will make the fault expand, and it needs to be quickly suppressed compared to other overvoltages [6-7].

At present, the arcing coil is used to solve the arc grounding faults. The inductor current generated by the arc suppression coil itself is used to compensate the grounding capacitor current of the grid, and the grounding current of the fault point is reduced, so that the grounding arc of the residual current is easily extinguished. When the arc is extinguished when the current crosses zero, the rising speed of the fault phase recovery voltage can be reduced to avoid arc reignition; in addition, the arc suppression coil can also reduce the amplitude of the single-phase grounding overvoltage, thereby limiting the damage of the ground fault. Improve the reliability of power grid supply. However, with the expansion of the distribution network and the increase of various types of loads in the power grid, the arc-extinguishing effect of the arc-suppression coil has been seriously affected.

Since the introduction and use of zinc oxide varistor tablets, their rapid development has been remarkable, characterized by good nonlinear characteristics and large energy capacity (surge absorption capacity), high-energy nonlinear damping. The material, namely high-energy zinc oxide varistor, has also been rapidly developed in the past decade, and has been applied to surge absorption and

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over-voltage protection of various large energies, and has broad application prospects. However, in the practical application process, the zinc oxide varistor chip needs to consider its charging rate, so that its threshold voltage will be taken higher, so that when it is used, it will not be effective overvoltage when it encounters a large energy operating overvoltage. Protective effects.

Current status and development trends of research levels at home and abroad:

In order to solve the problem of cutting off the no-load transformer, line single-phase intermittent arc grounding and line three-phase short-circuit over-voltage, the current domestic and international main grounding methods, improve the technical parameters of nonlinear damping materials and improve the performance of the circuit breaker body and improve the operation switch Research on control technology.

In the grounding method, the main measures for limiting the arc grounding voltage at home and abroad are as follows: 1) The neutral point is directly grounded or the neutral point is grounded through a small resistor. The neutral point is directly grounded or the small resistance grounding method can be well eliminated. Over-voltage when the arc is grounded, but this method expands the fault current at the single-phase grounding, which aggravates the burn at the fault point. When a single-phase grounding occurs, the excessive fault current directly causes the protection device to trip, sacrificing the pair. User power supply reliability. 2) Faulty grounding resistance, the arcing grounding overvoltage is essentially the oscillation caused by the redistribution of energy in the grid after a single-phase grounding short circuit occurs, and the resistance increases due to the resistance of the fault grounding point. The energy makes the overvoltage multiple and the neutral point voltage smaller. Therefore, in order to consume energy, it is considered to input the fault phase resistance to consume energy to suppress the arc grounding overvoltage. However, the neutral line ungrounded system fault line selection accuracy is not very high, which may lead to misoperation, which is not conducive to the rapid and accurate suppression of arc grounding overvoltage. 3) Taking measures to install the phase-to-phase capacitor bank, the intermittent arc grounding overvoltage is mainly caused by repeated arcing during the arcing, causing repeated changes in the grid operating conditions, resulting in electromagnetic oscillation of the inductor-capacitor loop in the grid, and the phase-to-phase capacitance is over the arc. The voltage has a suppressing effect, and the effect of suppressing the maximum overvoltage can be achieved by adding a certain phase capacitance. However, the thoroughness and rapidity of this method are not enough. 4) The neutral point is grounded by high resistance. After the neutral point is grounded by high resistance, the electromagnetic oscillation between the inductor and capacitor can be limited, thereby effectively suppressing the arc grounding overvoltage and not reducing the reliability of the system like a small resistor. When the neutral point is grounded through a large resistor, the fault current can still be limited to a small level, and the system can continue to operate without tripping. However, the high-resistance grounding has a limited application range and should only be applied to smaller-scale 10kV and below power grids. 5) The neutral point is grounded by the arc suppression coil (resonant ground). The arc suppression coil is a kind of

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adjustable inductance coil with an air gap and is installed at the neutral point of the distribution network. When an instantaneous single-phase ground fault occurs in the system, it can be eliminated by the arc-suppressing coil to ensure that the system is continuously powered; when it is a permanent single-phase ground fault, the arc-suppression coil can still maintain the system for a certain period of time, which can make the operating department have enough The time to start the standby power supply or transfer load will not cause passive; when the system is single-phase grounded, the arc-suppression coil can effectively avoid the arc grounding over-voltage, which protects the whole network power equipment, and is currently a common method for suppressing arc grounding over-voltage. . However, the system with arc suppression coils is more complicated to operate, and it is difficult and costly to achieve selective grounding protection. 6) The neutral point is grounded by a non-linear resistor. This method can effectively reduce the over-voltage level, which not only has the advantage of uninterrupted power supply during single-phase grounding, but also has short-circuit impact on the equipment, and the heat capacity requirement for the nonlinear resistor. not tall. However, since the commonly used zinc oxide varistor conduction voltage is not zero, the arc cannot be extinguished immediately after the device is operated, and the arc cannot be re-ignited after the arc is extinguished; once the arc is extinguished and no longer reignited, the system capacitor current will be completely Through the non-linear resistance of zinc oxide, the non-linear resistance of zinc oxide can only be maintained for a short time, and it is still impossible to avoid forced power failure.

In terms of improving the technical parameters of nonlinear damping materials, it mainly includes solving the energy flow capacity, the number of flow times, and improving the stability of materials and the consistency of components. 1) In terms of energy capacity and flow rate of materials, the high-energy zinc oxide varistor (outer diameter Φ115mm, inner diameter Φ23mm, thickness 15mm) used on the DC thyristor circuit breaker developed by Toshiba and Matsushita Electric Industrial Co., Ltd. The energy capacity is called 20kJ. The component is resistant to impact (20kJ each time) up to 10,000 times. After injecting 23 kJ of energy, the surface temperature rise of the element was only 39 °C. Hitachi has done a lot of work to improve the uniformity of the valve plate. The valve with an outer diameter of 130mm, an inner diameter of Φ53mm and a thickness of 22mm has an energy capacity density of more than 400J/cm3 and absorbs the energy of the overvoltage. Above 15kJ/kV, the most uniform film has a capacity density of 700J/cm3, and the corresponding single-chip energy capacity is 170kJ. The domestic general level energy density is 300J/cm3, and the higher level is 400J/cm3, which is close to the foreign level. The valve has a diameter of Φ90mm and a thickness of 9mm. The energy capacity of the valve is 15kJ, and the residual voltage of 10mA DC is about 400V. 2) In terms of material stability, the high-energy products of Toshiba and Matsushita Electric Industrial Co., Ltd. have a life expectancy of more than 100 years at 70% DC charge rate, and 60% AC and DC load of high-energy products of Panasonic Corporation of the United States. At the electric rate, it also passed the accelerated aging test at 1000 °C for 1000 hours, and the rate of change of V1mA was not more than 10%. There is no uniform and systematic test of the aging characteristics of high-energy products by domestic manufacturers. 3) In terms of

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component consistency, there is a big gap between domestic products and foreign products. The high-energy products of Toshiba and Matsushita Electric Co., Ltd., the dispersion of V1mA is controlled below 1% (±0.5%), and the volt-ampere curve is basically coincident. In this case, the natural combination of the valve plates and the current sharing problem at high currents are solved. The dispersion of domestic products is large, and the dispersion of the V10mA voltage of the valve produced in batch can only be controlled within 10% of the soil. Although some measures have been taken to improve the current sharing under current, it tends to deteriorate the uniformity of the small current region, which is not conducive to stability under long-term operating voltage.

In terms of improving the performance of the circuit breaker body and improving the operation switch control technology, 1) in terms of the circuit breaker body, there are three main measures currently taken: a) Improve the production process of the vacuum switch and improve its mechanical characteristics. In terms of the production process of the switch, in order to enhance the arc extinguishing capability of the vacuum interrupter, it is possible to improve the quality of the contact material and reduce the re-ignition rate. In addition, in order to avoid the induction of heavy breakdown, in the design of the arc extinguishing chamber, the contact and the shield cover should have suitable surface conditions as much as possible to reduce the heavy breakdown caused by the particles. In terms of perfecting its mechanical characteristics, it should be considered from the aspects of reducing the closing bounce of the vacuum circuit breaker, the bounce of the opening of the vacuum circuit and the different phases of the three phases. b) Reduce the total number of adhering impurity particles on the surface of the arc extinguishing chamber by the "old refining" test, that is, improve the cleanliness of the arc extinguishing chamber. The particulate matter will decompose and vaporize under the action of the arc generated by the breaking current of the switch, releasing a large amount of gas, thereby causing the insulation strength of the arc extinguishing chamber to decrease, resulting in heavy breakdown or severe breakdown of the switch, relatively clean. The higher the degree of switching, the less likely the heavy breakdown will occur. Electrical aging test is generally carried out before the vacuum interrupter is shipped from the factory. Common methods include current method and high pressure method. c) Use no re-ignition switch. The non-re-ignition switch can ensure the normal operation of the switch and the shunt capacitor and the reliability and safety of the power grid. However, it is very difficult to achieve the re-ignition of the switch from the technical point of view. From the current level of vacuum switch manufacturing in China.

3. Research key points

3.1. A brief description of the principles of the research content

In view of the practical problems of various overvoltages occurring in the power grid, combined with the advantages and disadvantages of zinc oxide varistor sheet materials, the research and product development of grid overvoltage suppression and

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current limiting protection devices based on high energy nonlinear damping materials are carried out. The device can completely absorb the energy when the overvoltage occurs, suppress the energy oscillation from the source, and realize effective damping of various overvoltages of the phase-phase and phase-ground, and the generator, the power transformer and the high-voltage motor in the power system. Such weak insulation equipment can fully play a positive protective role and improve the safety and reliability of the power grid.

3.2. Key and difficult points of project research

(1) Topological research on grid overvoltage suppression and current limiting protection based on high energy nonlinear damping materials

Because this topology research work must first consider the removal of no-load transformers, single-phase intermittent arc grounding and three-phase short-circuit multi-type over-voltage scenarios, and also need to meet the phase-phase, phase-ground simultaneous applicability, in addition to the need to design new The configuration principle of each component parameter in the current-limit topology realizes a new type of topology plus device to solve many types of over-voltage problems. Therefore, the topology over-voltage suppression and current-limit protection device based on high-energy nonlinear damping materials is the difficulty of this project.

(2) Development of overvoltage suppression and current limiting protection device based on high energy nonlinear damping material

The development of the protection device must not only accurately control the formulation elements to meet the technical requirements of the corresponding parameters, but also need to fully consider the actual installation position and operating environment of the protection device, so it is necessary to strictly control the firing and heat treatment in the process of the device trial production. Process, and through heating dehumidification and layered heat curing and encapsulation to ensure the insulation and sealing structure of the device inside and outside, in addition to the need to optimize the appearance and size of the protection device to meet the limitations of the field operating space, so the grid based on high energy nonlinear damping material The development of overvoltage suppression and current limiting protection devices is another difficulty in this project.

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