Study on the Transient Process of 500kV Substations Secondary Equipment

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Abstract. By analyzing on the reason of the lightning accident occur in the substation, the way of lightning incoming surge invading the secondary system is summarized. The interference source acts on the secondary system through various coupling paths. It mainly consists of four ways: the conductance coupling mode, the Capacitive Coupling Mode, the inductive coupling mode, The Radiation Interference Model. Then simulated the way with the program-ATP. At last, from the three aspects of low-voltage power supply system, the impact potential distribution of grounding grid, the secondary system and the computer system. The lightning protection measures is put forward.

1. Introduction
At present, the external lightning protection measures of substations have been quite mature, and the lightning damage accidents generally do not occur. For the secondary system lightning protection, Most of domestic substations have taken less measure. With the increasing use of large-scale integrated circuits in substations, especially with the improvement of voltage level, more advanced microelectronic devices are required to monitor, and measure and protect the primary system. Such as the secondary equipment of relay protection, automatic, remote, remote control, telemetry, communication equipment etc. These microelectronic devices withstand extremely low voltage levels, essentially only around 10v. If we do not take effective lightning protection measures, these fragile devices cannot work properly, which is a serious threat to the safe and stable operation of power systems.

2. The coupled way of interference
The interference source acts on the secondary system through various coupling paths. There are two ways to transfer interference energy from jamming source to jamming object: the conduction mode and the radiation mode. The conduction coupling mode refers to the electromagnetic energy of the interference source in the form of voltage or current coupled to the secondary system through the metal wire, resistance, capacitance and inductance. It can be divided into the conductance coupling mode, the inductive coupling way, and the capacitive coupling mode[1].

2.1. The conductance coupling mode
As shown in Figure 1, when 2 or more circuits share a total of 1 line or 1 connection, the common mode impedance coupling may be generated. The common mode impedance may be caused by the...
leakage of the ground or the leakage conductance of the circuit. A circuit current in another circuit interference voltage, the interference level depends on the common mode impedance.

\[ I = C \frac{du}{dt} \]  

In the formula:
- \( I \) - The Current Which Is Through The Circuit Capacitance
- \( C \) - The Capacitance Between two circuits
- \( \frac{du}{dt} \) - The First Circuit Voltage Change Rate

For capacitive coupling, the coupling decreases with increasing distance between conductors, and high impedance circuit is more conducive to capacitive coupling[2].

2.3. The inductive coupling mode
The magnetic field generated by a circuit may be inductively coupled to another circuit, which is caused by the mutual inductance between the interference source and the interfering object. When a large current through the loop, it is bound to create a magnetic field around it, which should be out in secondary system on the interference voltage in the vicinity of the system. Especially in the event of an accident, sudden changes in the current in the primary circuit will cause strong electromagnetic induction.
There is a closed loop in different circuits of any system. The inductance of these circuits is directly proportional to the area of the loop, as shown in figure 3. The role of the circuit is essentially the interaction between the source and the sensitive circuit. Even DC circuits can produce a varying magnetic field when they are cut periodically or intermittently[3].

When the current of a circuit changes, the area of the loop will produce a changed electromagnetic field. The induced voltage is generated when the magnetic flux passes through another loop, and the magnitude of the induced voltage is proportional to the area of the magnetic flux generated by the circuit. The induction voltage is determined by the following formula:

\[ E = M \frac{di}{dt} \]  

(2)

\( E \) - Induced Voltage of the Secondary Circuit;
\( M \) - Mutual Inductance;
\( \frac{di}{dt} \) -The Current Rate of First Circuits.

2.4. The Radiation Interference Model

The radiation interference refers to electromagnetic interference, resulting in first system of radiation interference energy transmitted through space in the form of electromagnetic waves to the secondary system, interference, with two cable grounding modes formed in different common mode and differential mode interference. The high frequency signal generated by the external source transfers a considerable amount of energy to the control circuit through the radiation coupling. The interference frequency is generally much higher than the frequency response of the control circuit, but if they are modulated by the frequency or its harmonics, then the control circuit of the pickup and counter modulation, it will cause trouble, the process of picking and counter modulation will produce spurious signal in frequency signal[4].

The coupling of the interference source to the secondary circuit is very complex, and there are several kinds of interference sources and several jamming modes.

3. Simulation of line lightning surge invasion to secondary system

3.1. Introduction of ATP

ATP (Alternative Transient Program) is one of the world’s most widely used EMTP version, the ATP-EMTP program is almost free for everyone in the world, and can run on most types of computers. Especially it is very convenient to use the recently developed graphical input program ATPD raw—by drawing the circuit diagram, inputting data in the interface, creating data files with the computer.

3.2. Modeling

The lightning surge invades the bus by the transformer substation, then goes through the electrostatic and electromagnetic coupling between transformer high voltage winding and low voltage winding, and gets into the low-voltage outlet, then goes through the line lightning arrester, bus arrester and other multi peak clipping, and then the voltage amplitude greatly decreased with the flat-wave effect by passing the transformer low-voltage output. But because of the large peak amplitude and the large energy of lightning surge, although the lightning wave goes through the above arrester, most of the
energy can be eliminated, but there is still some of the lightning surge goes through the transformer low-voltage outlet in the form of relatively low energy spikes with relatively high amplitude and very short duration of action, then added to the 380V AC circuit and the secondary circuit of substation. The model of lightning surge invasion to weak current equipments is established combined with the lead-in line in Fig.4.

**Figure 4.** The model without consider effect of inductance

In this simulation analysis, lightning current waveform adopts the national standard 2.6/50 $\mu$s, the amplitude of Slope-rampis is 10kA. The volt-ampere characteristic of the arrester is as follows: The simulation results are as shown in Fig.5.

**Figure 5.** Voltage waveform of micro-electronics device two ends

If considered the effect copper equipotential connecting line in the lightning current and other high-frequency interference, equivalent to the exist of inductance, the model is established as follows in Fig.6.

**Figure 6.** The model consider effect of inductance
Generally copper inductor is 0.5-0.8μH/m, we choose 0.6. The length of copper is 200m, so the inductance value is 1.2mH.

The simulation result is shown in Fig.7.

![Image](image-url)

**Figure 7.** Voltage value of secondary equipment two ends

At this time, the voltage added to the secondary system devices can reach the maximum voltage of 433911.1V. This result is in a difference of nearly more than ten thousand volts without considering the effect of inductance, so the inductance effect of copper in the lightning current and other high-frequency interference can not be ignored. In practical applications, the equivalent length of the size of the copper row Should be minimized. Thereby it can reduce ground potential interference.

4. Measures for Preventing Lightning Interference in Weak Current System of Power Plant and Substation

4.1. Improvement of Lightning Protection for Low Voltage Power Supply System

Lightning through the low-voltage power supply system on the computer and other weak electrical system is more dangerous, so low-voltage power supply system lightning protection is particularly important. In order to prevent the lightning accident of the low-voltage power supply system, the following lightning protection measures should be adopted at low voltage:

(1) In the factory, the appropriate voltage level of zinc oxide arrester is installed in the low-voltage side of the transformer for protection;

(2) Device of the cascade surge absorption is installed In front of the power of microcomputer protection and integrated automation

4.2. Improving the impact potential distribution of grounding grid to prevent ground potential interference

To reduce the grounding resistance limit potential rise, especially in the increase of vertical grounding and radial horizontal grounding which can reduce the grounding resistance in the lightning arrester under frame and to prevent the lightning into the ground caused by the local ground potential to the secondary cable counterattack.

The distribution of ground potential is improved to protect the local potential increasing. Square hole network should be used to improve the ground potential distribution in the design of grounding grid. The horizontal pressure equalizing zone is set up in order to improve the electric potential of the cable trench, and to prevent the disturbance of the earth potential to the two circuit[5].

4.3. Improve the secondary circuit and computer systems to prevent the interference of shielding

To strengthen the electromagnetic shielding of the control room to prevent the electrostatic interference caused by lightning activity, and the impact of the magnetic field interference caused by lightning on the computer system.

Shielded cable is used on the power plant, substation secondary cable to prevent the over-voltage or electrostatic induction in the secondary circuit induced by the lightning activity.
5. Conclusion

Lightning protection of substation in secondary system is a systematic project. To take shielding, voltage sharing, install SPD and other multiple measures, we can take three-level protective measures. Carry out the comprehensive management of electronic information lightning protection, the overall defense, grading discharge, successive defence ideas. For the moment, lightning protection of substation in secondary system is still a new topic. How to better protect, but also the need for further study of the relevant units.

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