

Study on Mitigation Measures for Electrical Interference of AC Substation on Pipeline

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ABSTRACT

A single-phase ground fault of the AC substation will cause electrical interference to the adjacent pipeline, mainly reflected in the touch voltage, step voltage, and coating breakdown voltage of the pipeline exceed the safety threshold. In order to evaluate the electrical interference effect of an AC substation on adjacent pipelines, the numerical simulation method is used to calculate the relevant safety parameters of the pipeline during the single-phase ground fault of the substation. For the case of touch voltage of the pipeline exceeding the safety threshold, the mitigation methods have been obtained by the software calculation. The specific mitigation method is to connect the pipeline to the grounding of the valve room through the solid state decoupler, and then set the gradient mitigation line in parallel with the pipeline near the substation.

Keywords: AC substation; Pipeline; Valve chamber; Electrical interference

INTRODUCTION

A substation is a place where the power system converts voltage and current and receives and distributes electric energy. When a phase line is abnormally connected to another phase line or ground, a large amount of current will flow into the ground through the grounding bed of the substation. In such case, if metal structures exist such as buried pipelines near the substation, the pipelines often withstand serious electrical interference ¹, which causes stray current corrosion of the pipelines ² and other safety problems. The pipelines are affected by inductive coupling and resistive coupling on a position near the grounding electrode of the substation, instant high current pulse arising from fault current or lightning current discharge may cause damages to external anti-corrosion coating and even pipeline metal, auxiliary equipment and discharge protection devices ³. The extent of damages is dependent on the distance between the pipeline and the grounding body of the substation, magnitude of the fault current or lightning current, duration, soil resistivity, pipeline parameters and factors ⁴. Therefore, in some cases where a specific pipeline is disturbed by the substation, we need to

determine the degree of influence of the substation on the pipeline through specific analysis and calculation.

A natural gas pipeline has a diameter of 1016mm and the coating is applied with 3LPE, with a thickness of 3mm, the burial depth is 1.5m and the soil resistivity is $30\Omega\cdot\text{m}$. The voltage of the AC substation is 220KV, and the parallel spacing between the external wall and the pipeline is 20m. A distribution valve chamber is set up upstream of the pipeline at 80m away from the substation. As shown in figure 1.

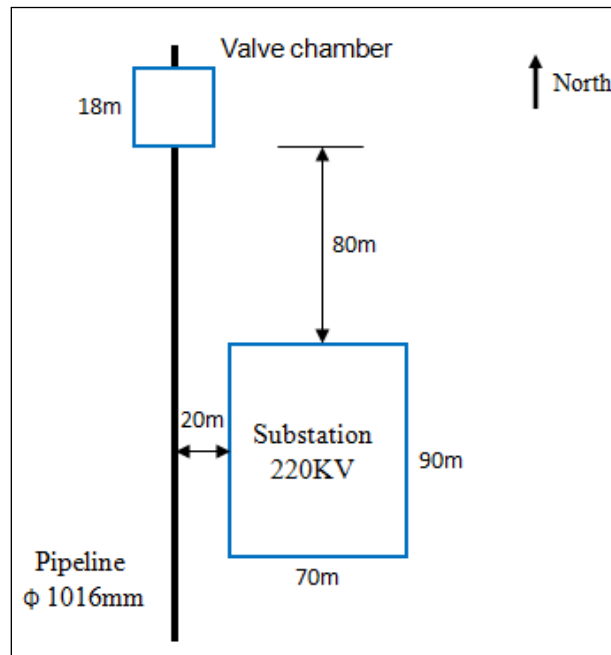


Figure 1 Schematic diagram for relative positions of pipeline and substation

According to the standard of SY 0007-1999 and SY/T 5919-2009, the distance between the pipeline and the grounding electrode of the 220KV power station or substation shall be greater than 30m; According to GB50251-2015, GB50698-2011 and Oil and Natural Gas Pipeline Protection Law, for various grounding devices of the AC transmission systems with a voltage not higher than 220KV, the minimum horizontal distance to the buried pipeline is 5m. According to the above standards, there is controversy about the safety distance between the buried steel pipeline and the power station or substation. In this case, the distance between the pipeline and the grounding electrode of the substation is 20m, and the parallel spacing is 90m. The distance between the distribution valve chamber of the gas transmission pipeline and the substation is only 80m. Does fault current of the substation affect the safety of pipeline and valve chamber operators? Hence, in this case, by using field monitoring and numerical simulation techniques, the influence of the substation on the pipeline is comprehensively evaluated, and the countermeasures are given.

Electrical interference mechanism

In case of single-phase ground fault of the AC transmission line, a large amount of current will flow into the ground through the grounding electrode, thus increasing the soil potential near the grounding electrode. If a pipeline is buried near the grounding electrode, the high potential exists in the soil around the pipeline, while the potential of the pipeline maintains a very low level under the protection of the coating, so a high potential difference will be formed between the pipeline and soil. Voltage that a person withstands at the time of touching an exposed metal facility connected to the pipeline nearby is called as contact voltage. The contact voltage is related to fault current, the spacing between the grounding electrode and the pipeline, soil resistivity and impedance of pipeline coating.

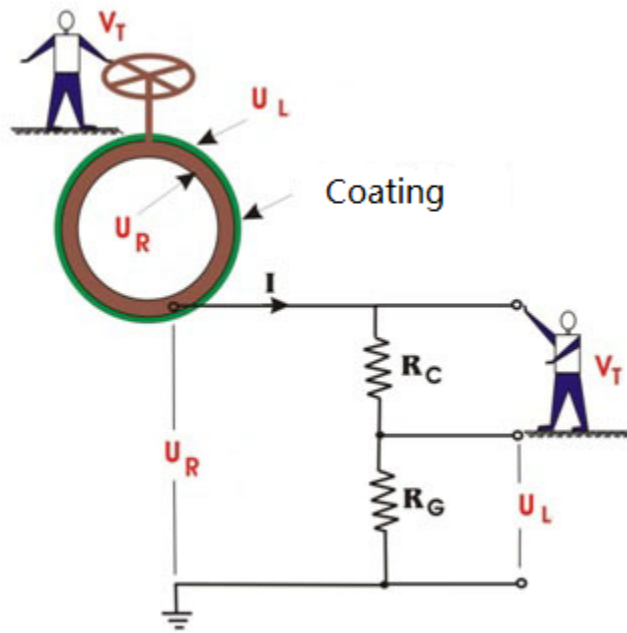


Figure 2 Schematic diagram of different kinds of potential

In figure 2, V_T is the contact voltage; U_R is the potential rise of the pipeline metal; U_L is the potential rise on the corresponding position; R_C is the resistance of the coating; R_G is soil resistance from this position to a very distant place, and I is the leakage current.

The permissible values of contact voltage and step voltage can be calculated by the methods as specified in GB/T 50065-2011, as shown in formulas (1) and (2).

$$U_t = \frac{174 + 0.17 \rho_s C_s}{\sqrt{t_s}} \quad (1)$$

$$U_s = \frac{174 + 0.7 \rho_s C_s}{\sqrt{t_s}} \quad (2)$$

In which,

U_t Permissible value of contact potential difference (V)

U_s Permissible value of step voltage difference (V)

ρ_s Rate of resistivity of the surface layer ($\Omega \cdot m$)

t_s Duration of ground-fault current

C_s Surface attenuation coefficient

The surface attenuation coefficient C_s is calculated according to formula (3):

$$C_s = 1 - \frac{0.09 \times (1 - \frac{\rho}{\rho_s})}{2h_s + 0.09} \quad (3)$$

ρ_s is the rate of resistivity of the surface layer ($\Omega \cdot m$)

ρ is the rate of resistivity of the second surface layer ($\Omega \cdot m$)

h_s is the thickness of the surface layer ($\Omega \cdot m$)

In general, the fault current of the 220KV substation is cleared in 0.5s, and the soil resistivity on the position where the substation is located is $30 \Omega \cdot m$. Therefore, the safety limit of the contact voltage along the pipeline and the valve chamber is 253V, while the safety limit of the step voltage is 276V.

Calculation and analysis

3.1 Calculation of interference level

The pipeline size is 1016×18mm. In the calculation model, the pipeline length takes 10km. Both ends of the pipeline are connected with a 200m long ground rod so as to replace the metal structure connected to the pipeline. The relative resistivity of pipeline steel takes 17 (relative to annealed copper), and the relative magnetic conductivity is 1.0 (relative to vacuum). The coating is 3LPE, with a thickness of 3mm and the burial depth of the pipe is 1.5m. The average soil resistivity in this area is 30Ω•m, and the parallel spacing between the pipeline and the external wall of the substation is 20m.

The voltage of the AC substation is 220KV, and the grounding electrode is distributed below the substation. The horizontal grounding electrode is buried at a depth of 0.8m, and the vertical grounding electrode is 2.5m long. The spacing between the grounding electrodes is 5m, and the size of the grounding electrode is 90m L×70m W. The grounding resistance is 0.5Ω. In case of single-phase ground fault, the ground current is 5KA.

The calculation model is shown in figure 3.

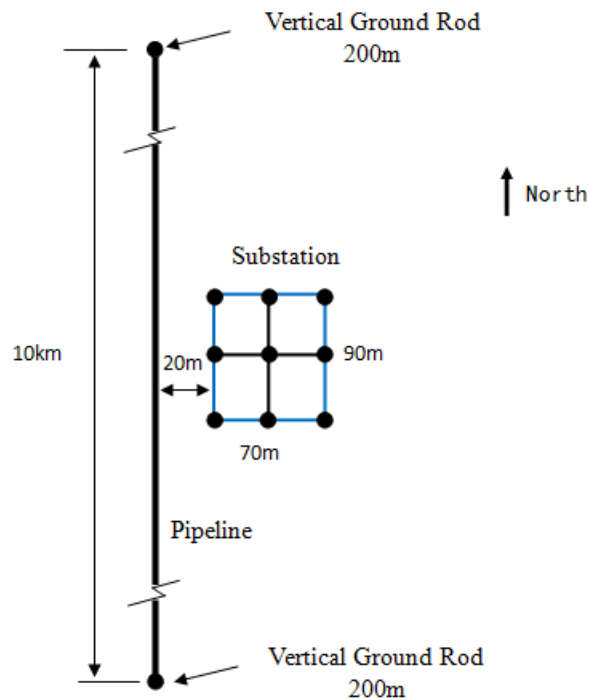


Figure 3 Schematic diagram of calculation model for numerical simulation

The calculations are shown in table 1.

Table 1 Assessment of pipeline safety limit in a fault state

Physical quantity to be assessed	Calculated value (V)	Permissible value (V)	Whether the safety limit is exceeded
Maximum pipeline metal GPR	11	\	\
Maximum contact voltage along the pipeline	425	253	Y
Maximum step voltage along the pipeline	3.3	275	N
Maximum coating breakdown voltage	425	57000	N