Stray Alternating Current Problems in Concrete Power Poles

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High-voltage alternating current (AC) can leak through the surface of insulators and enter concrete poles. This can create problems that may affect the power network, such as the release of power cables from clamps, melting and cracking of insulator surfaces, melting of the insulator, and degradation of the concrete poles. This article explains how stray AC damages power poles, and outlines methods to prevent it.

Stray current is defined as current that flows through unwanted paths.[1] Current leakage from high-voltage power lines through a concrete pole can damage the concrete and cause other serious problems in power networks.

High-voltage power lines are isolated from the ground by some electrical resistances. The resistances are not constant and vary with ambient effects. If concrete pile quality and technology are low, a deposit layer from air pollution forms on the insulators, and if grounding systems do not work well, high-voltage alternating current (AC) can creep from the surface of the insulator into the concrete pole.

Problems Encountered

Release of Cable from Clamp

Creep of high-voltage AC from the surface of the insulator can release a power cable from a clamp. Figure 1 shows a typical clamp before and after the effects of creeping AC from the surface of the insulator. The stray AC was high enough to burn and melt the contact surfaces of the cable and clamp. In this condition, the compressive force of the clamp on the power cable is reduced and the cable releases from the clamp.

This occurs in regions with polluted air. Pollution and moisture from the air cause oxidation of the clamp and cable contact surfaces. Electrical resistance of the clamp contact surface increases and high electric heat is generated in the clamp when high stray AC occurs. Resistance between the clamp and cable increases as the oxide layer on the surface of the clamp and cable is formed.

To mitigate this problem, air and water clamp seals have been installed.

Grounding System

Grounding high-voltage power transmission systems is different than grounding low-voltage power distribution systems. In the power transmission system, lightning arresters are used. In the power distribution system, one phase of power has been grounded (Figure 2). In both cases, the grounding system and concrete pole are two electrical parallel paths that pass stray current, and the amount of electric current in each path depends on its resistance.

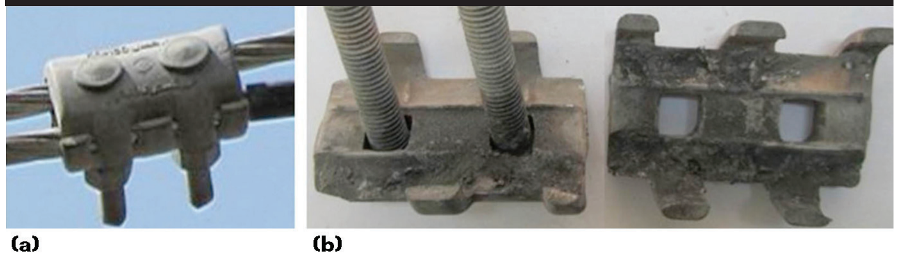
The lightning arrester is a non-continuous grounding system and it will close in specified high over-voltage such as lightning. In the special conditions explained previously, some current can leak to the concrete pole. In the area that was investigated, there were other problems—the grounding resistance was high (>50 Ω) and most of the grounding cables were cut and stolen. Under such conditions, stray current through concrete poles can be increased during rainfall. Therefore, the grounding systems were repaired and their resistance reached 3 Ω.

Concrete Poles

In some concrete poles, the concrete cracked after the rebar had corroded; but in others, rebar corrosion occurred after the concrete cover had cracked. The cracks were vertical and parallel, and weren't similar to cracks caused by an alkali silica reaction (Figure 3). Based on field observations, stray AC occurred during rain, when the concrete pores absorbed water and reduced the concrete's electrical resistance. That caused rapid warming of the concrete pole, which released water vapor from its surface. Meanwhile, a slow "jik-jik" sound was heard, which was related to initiation and propagation of cracks.

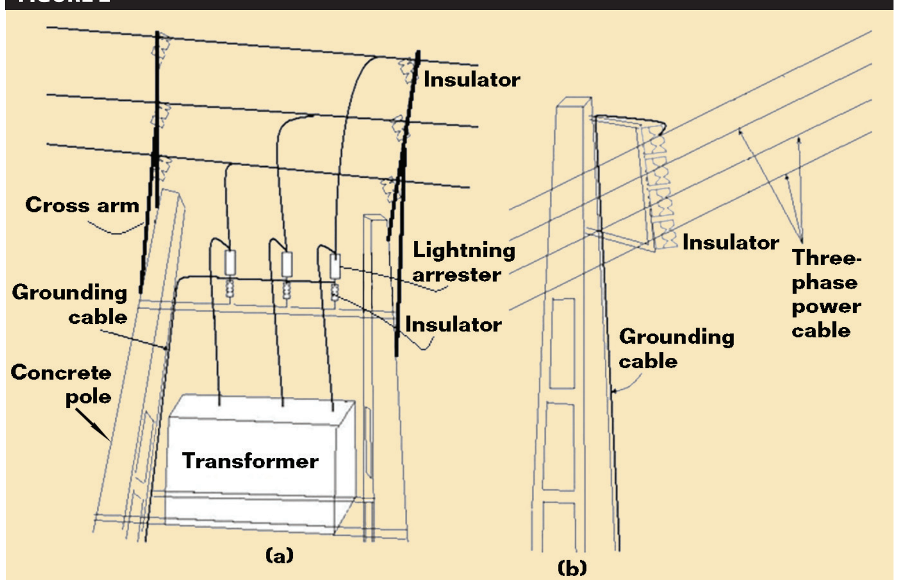
Thermal stress and shrinkage stress from rapidly drying concrete pores caused micro- and macrocracks in the concrete pole.[2] These cracks increased the permeability and reduced the

FIGURE 1



(a) A typical clamp before and (b) after the occurrence of stray AC in a power concrete pole.

FIGURE 2

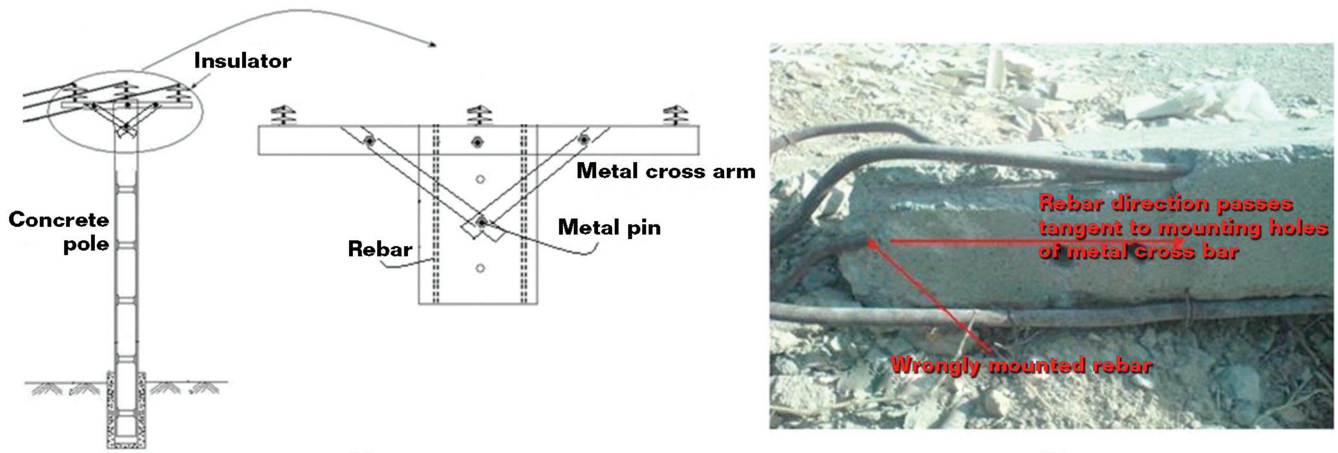


(a) Grounding in a high-voltage power transmission system and (b) grounding in a power distribution system.

FIGURE 3

Cracks in concrete power pole caused by stray AC.

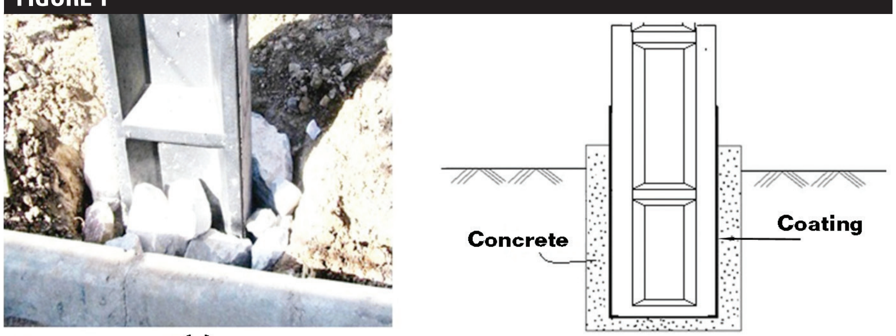
FIGURE 1



(a) (b)

(a) Insulators mounted on a metal cross arm, and (b) the location of rebar in a destroyed concrete pole, which is very close to a hole for mounting a metal pin. As observed, one of the rebar is tangent to the holes.

FIGURE 1



(a) (b)

Large stones alone must not be used as backfill in a mounting cavity. (a) Incorrect mounting and (b) a correct mount.

durability of the concrete. The concrete cover cracked and then rebar corrosion started.

Solutions Used

Concrete Quality

Two types of concrete power poles were used in the study area: circular cross section (CCS) and rectangular cross section (RCS). Based on field observations, the CCS poles had good durability without any stray AC cracks or rebar corrosion.

The RCS poles were manufactured by pouring concrete into a mold. The water/cement ratio selected was ~0.6. The CCS poles were manufactured by centrifugal casting and water was removed by centrifugal force before curing. Thus, the total volume of pores in the CCS pole should be much less than the RCS pole. For this reason, the RCS pole absorbed much more water than the CCS pole. Therefore, the reduction of electrical resistance of the RCS pole in the rain should be much greater than in the CCS pole, and high stray AC should occur only in the RCS poles. Also, with a lower total volume of capillary pores, concrete permeability decreases.[3] For this reason, the CCS poles had good durability. The RCS concrete poles were replaced with CCS poles.

Insulator Mounting

Insulators can be mounted directly or indirectly on power poles. In the direct method, insulators are mounted on a power pole without a cross arm; but in the indirect method, cross arms are used to mount insulators on power poles.[4] Cross arms are made of metal, wood, or pultruded polymer composite. It is much more difficult for current to creep from the surface of insulators mounted on nonmetal cross arms than insulators mounted on metal cross arms.

In the area of study, metal cross arms had been used for mounting insulators on the power poles. The metal cross arm was connected to the concrete pole with several metal pins. As shown in Figure 4, the pins passed close to the rebar. In rainy conditions, the concrete became saturated with water and the empty space between the metal pins and concrete filled with water. The resistance between the power lines and ground was reduced considerably and the probability of current creep on the surface of the insulators increased. Therefore, the metal cross arms were replaced with polymer composite cross arms.

Concrete Power Pole Mounting

The method of mounting the concrete poles in the ground is another important factor that influenced the occurrence of stray AC. Increasing the resistance of the backfill and increasing water drainage around the concrete pole decreases the probability of current leakage from power lines. Also, application of a coating on the buried portion of the concrete pole increases the electrical resistance to the ground and decreases the probability of the occurrence of stray AC.

In the study area, large stones were used for mounting the concrete poles (Figure 5[a]). In such conditions, there was considerable empty space between the stone, which could fill with rain water. This caused the buried portion of the pole to be saturated with water, which decreased electrical resistance and increased the probability of stray AC. To solve this problem, the concrete poles were mounted in the ground, according to Figure 5(b). In this condition, a concrete mix of 350 kg/m^3 Portland cement, 1,145 kg/m^3 aggregate (<5 mm), 199 kg/m^3 aggregate (5 to 10 mm), 558 kg/m^3 aggregate (10 to 20 mm), 2% super plasticizer, 10% silica fume, and a water/cement ratio of 0.45 was used to mount the poles.

Conclusions

All factors that increase the electrical resistance of concrete power poles decrease stray AC. Therefore, the use of non-metal cross arms, increased creepage distance of insulators, increased water drainage in areas where concrete poles are mounted, and application of a coating on the buried portion of the concrete pole can improve resistance of concrete poles to stray AC.

High-strength concretes with a low volume of capillary pores are suitable for power poles. Low-strength concretes with a high volume of capillary pores have a high water absorption in rain, one of the reasons that stray AC occurs.

After implementing all these modifications, stray AC problems were eliminated in the area of investigation.

References

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