Effects of Highly Polluted Atmospheres on Power Distribution Systems

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Air pollution has destructive effects on power pole insulators and electrical fittings. Usually, ferrous electrical fittings on power distribution poles are galvanized. Unfortunately, in highly polluted atmospheres, galvanized layers have a limited lifetime. This article presents some of the destructive effects of air pollution on electrical fitting and explains strategies to counter the resulting corrosion.

Air pollution creates destructive effects on power distribution systems. It can decrease the durability of concrete power poles,[1-3] and also cause corrosion of electrical fittings such as power line clamps and metal cross arms, which allows electrical current creep across insulator surfaces. In some cases, the effects of air pollution have caused electrical power outages; destroyed insulators; increased the occurrence of fault currents; and released power lines from their clamps, permitting power lines to fall to the ground.

Isfahan, one of the largest cities in Iran, has a high level of air pollution caused by brick furnaces, and industrial and wastewater facilities. Air pollution is higher in two suburbs, Dolatabad and Habibabad, than in other parts of the city, and many serious power line problems there have been caused by air pollution.

In several Iranian cities, there are special devices for measuring air pollution. Isfahan has these devices, which are located in various areas of the city. They measure the air quality index (AQI) by first determining the average concentration of air pollutants per hour, including sulfur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), and carbon monoxide (CO), and the average concentration of solid particles suspended in the air (in a 24-h period) with a size of <2.5 µm ($PM_{2.5}$) and 10 µm (PM_{10}). Then the device automatically converts the measurements into the AQI, which has six levels: 0-50 (excellent), 51-100 (good), 101-150 (lightly polluted), 151-200 (moderately polluted), 201-300 (heavily polluted), and >300 (severely polluted). Figure 1 shows a typical air pollution measurement device used in Isfahan.

FIGURE 1 A typical air pollution measurement device used in Isfahan.

FIGURE 2 A rusty galvanized cross arm in the polluted atmosphere of Dolatabad.

TABLE 1. AQI OF ISFAHAN CITY IN DIFFERENT LOCATIONS ON DIFFERENT DATES

Date	Ahmadabad Square	Azady Square	Emam Hossein Square	Khajo Bridge	Kharrazi Freeway
12-25-2013	248	261	235	238	203
12-29-2013	302	310	273	301	356
1-16-2014	61	64	72	67	70
1-21-2014	162	163	171	159	177
1-24-2014	92	86	97	88	98

Galvanized Steel Structural Members

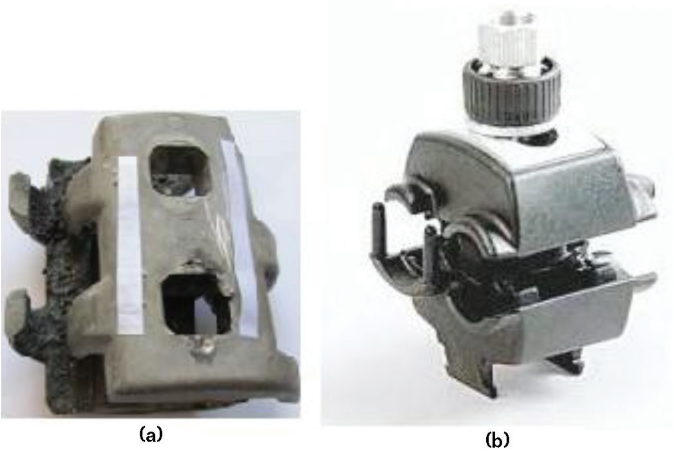
Galvanized steel generally has good atmospheric corrosion resistance. When exposed to the atmosphere, the zinc in galvanized steel converts to oxide, then to hydroxide, and finally to carbonate. Zinc oxide and hydroxide are not dense layers so they can't protect steel against corrosion. In contrast, zinc carbonate is a dense and protective layer. It has good continuity and adhesion to the substrate and can provide corrosion resistance for steel for a long time.[4] In Dolatabad and Habibabad, the thickness of galvanized steel on electrical fittings was ~100 µm. Its service life was very short, however, and after about five to six years, the fittings became rusty (Figure 2).

Atmospheric corrosion of galvanized steel is related to humidity and corrosive agents in the air, such as SO_2.[5] Table 1 lists the AQI of Isfahan's air at different locations. High levels of air pollution occur at the end of December and beginning of January (during the winter season). Unfortunately, there were no air pollution measuring devices in Dolatabad and Habibabad; however, the levels of pollution would be expected to be greater than levels listed for other areas of Isfahan (Table 1) because of the sources of pollution near these suburbs. In polluted air, humidity and SO_2 form sulfuric acid (H_2SO_4), which can dissolve the zinc carbonate layer on galvanized steel.

The carbonate layer has an important effect on the corrosion resistance of galvanized steel. When that layer is removed, underlying layers of the galvanizing are exposed to polluted air; therefore, the corrosion rate increases rapidly.[5] After a short time rusty conditions appear (Figure 2).

Because the zinc carbonate layer plays a major role in the corrosion resistance of galvanized steel in polluted air—when that layer is removed, corrosion of the galvanized coating accelerates—increasing the thickness of the galvanized coating isn't a suitable solution for high corrosion rates in polluted air.

When the zinc carbonate layer on clamps made of galvanized steel is removed by polluted air and the other layers of clamps made of galvanized steel corrode, ferrous oxides are formed on the surface of the clamp. This increases the electrical resistance of the clamp in contact with the power line. When fault current occurs, electrical heat in the corroded clamp is much higher than it would be otherwise. This heat has been high enough to melt the contact surface of the clamp and cause the power line to fall to earth. If an aluminum clamp is used, then its melting point from electrical heat will be lower than a steel clamp. Figure 3 shows a damaged clamp and a new clamp.



(a) (b)

FIGURE 3 (a) Melted contact surface of a clamp by fault current and (b) a typical new seal clamp.

The solution to this problem is to seal the contact surface of the clamp against polluted air.

Polymer Composite Structural Members

Polymer composite cross arms have good corrosion resistance in polluted air. They are nonconductors and can increase resistance against current creep across insulators. Therefore, they were proposed as a suitable alternative material selection for galvanized cross arms in Dolatabad and Habibabad. Figure 4 shows a typical polymer composite cross arm.

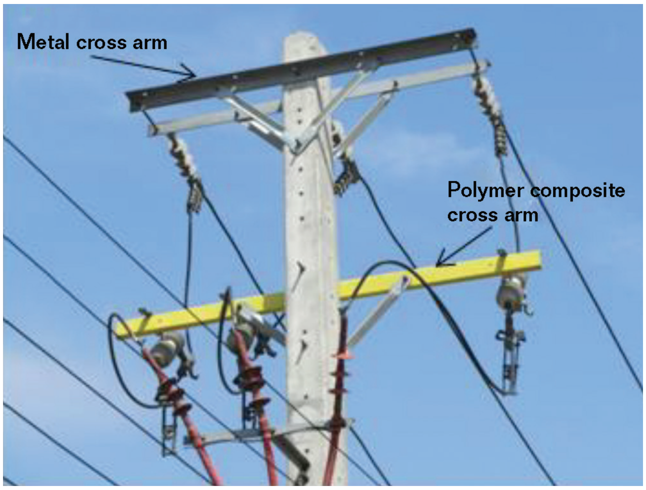


FIGURE 4 A typical polymer cross arm for use on concrete power poles.

Current Creep in Insulator

Polluted air forms a deposit on the surface of insulators. With increasing humidity, rain, or snow, the resistance of the deposit greatly decreases and high voltage current can creep onto the surface of the insulator and form a spark. Electrical heat from creep current exchanges among power lines, the grounding system, and power pole is high enough to melt the surface of insulators. When this occurs, a portion of the air pollution deposits diffuses into insulators and decreases their resistance. The surface of the insulator becomes rough and can attract additional deposits from polluted air. The next creep current may affect the surface of the insulator. This can punch holes in the insulator (Figure 5). In this condition, power lines may be released from their clamps when a fault current occurs and power is cut off.

FIGURE 5 Typical punching of the surface of an insulator after experiencing creep current.

The following solutions for creep current have been proposed:

- Increasing creep distance of insulators by replacing them with insulators that maximize the length of the leakage path.
- Periodic washing of insulators (weekly or monthly), especially during the winter season.
- Replacing metal cross arms with polymer composite cross arms.
- Increasing the quality of concrete power poles to increase their resistance against fault current.
- Modification of the grounding system.

Conclusions

Prevention of air pollution is the best method to mitigate the corrosion problems of electrical fittings. In polluted areas, replacing galvanized cross arms on concrete power poles with glass-reinforced polymer composite material is desirable. Doing so also reduces current creep across insulators in wet polluted air. Sealing the surface of cable clamps reduces damage to the clamps and the possibility of releasing a cable.

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