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An assessment of polyethylene insulator performance

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Summary

Porcelain insulators have proven to be unsuitable for insulated conductor applications, simply because the difference in dielectric constants between porcelain and polyethylene will eventually lead to electrical erosion of the polyethylene cable insulation. To solve this problem, electrical engineers are now considering insulators manufactured from high-density polyethylene that is compatible with polyethylene-insulated wire.

Historical context

Porcelain pin insulators were originally used with telegraph infrastructure in the 1850s and 1860s. Following the development of threaded glass insulators, which were less expensive to produce than quality porcelain, porcelain saw very minimal use. Yet this all would change with the proliferation of electricity.

As electric power distribution grew in the 1880s, larger and more reliable insulators were needed for the higher voltages of power lines. Glass was not equal to the task of insulating against tens of thousands of volts.

Porcelain was a superior insulating medium, and decision makers began to gravitate to it once again as the primary insulating material. Wet process porcelain – which is mixed wet, plunged in a mold, shaped on a wheel, and then dried, glazed, and fired at high temperatures – followed. If all the air was removed from the clay, wet process porcelain outperformed dry process porcelain. Various porcelain advancements and refinements followed through the late 1890s and early 1900s, such as glaze-welded porcelain, which involved assembling an insulator from multiple pieces. Yet as voltages grew, so did the demand for insulators capable of handling the load.

The 1940s saw the introduction of the "post" insulator, a single-piece solid or hollow-core porcelain column with multiple flanges from top to bottom. Their performance was superior to pin-type insulators, and by the 1960s they found widespread use on power lines everywhere.

The porcelain dilemma: Dielectric compatibility

Because porcelain has a higher dielectric constant, the covering of the conductor shares a higher portion of the voltage stress, which will cause tracking and erosion and eventual failure of the conductor.

When covered conductors are installed in open air under normal operating conditions, very little voltage appears across the covering. In fact, the voltage at the covering surface is almost full line voltage and there is negligible current passing through the insulation.

If the cable comes into contact with a partially grounded object (a tree branch, wet leaves, etc.), this situation changes. Now there is a path to ground and, as a result, an electric current flow. Covered conductors are not intended for permanent contact with grounded objects, since it will eventually cause covering damage and lead to system failure.

When a polyethylene-covered cable comes in contact with a porcelain insulator, there is also a path to ground. That path, made up primarily by the insulator, is a mixture of resistance, inductance, and capacitance. Unfortunately, since porcelain is a very different insulating material than the polyethylene, there is an electric field discontinuity at the interface where the cable touches the porcelain.

This contact point at the interface of the cable and porcelain insulator begins to experience partial discharge, or corona, which results from an unequal sharing of the voltage across the insulator and the cable covering. Eventual failure of the conductor is ensured.

NOTE: Dielectric incompatibility and corona are influenced by voltage level. Specifically, the higher the voltage, the greater the discharge and the shorter the time to covering damage or failure. On a 15kV system, it might take 20-30 years to actually see insulation degradation. On a 35kV system, however, the time for the corona to cause a burndown may be on the level of years or even months.

The emergence of polyethylene

The invention and use of polyethylene as an insulator material occurred in the mid-1960s. It was improved in years to follow as high-density polyethylene (HDPE) was developed.

HDPE insulators accomplish the benefits of increasing chemical resistance, low temperature properties, impact and tensile strength, and scratch resistance during the molding process. In addition, there is virtually no chance of chipping, cracking or breaking.

Polyethylene insulator performance characteristics

Barring damage from misuse, vandalism or poor quality control, porcelain insulators can have an expected service life of 50 years or longer. But the issue with porcelain insulators is not longevity; it is compatibility with today's conductors. This is where HDPE insulators excel.

Since their origination in the 1960s, and with the advent of high-density polyethylene Vise Top Insulators in the mid-1970s, millions of polyethylene insulators have been installed.

Qualitative research at Northeast Utilities, Arizona Public Service (APS) and Southern California Edison (SCE) found that polyethylene insulators have been used extensively with minimal failure rates across all three organizations. Additionally, the following performance attributes have been identified:

- Longer leakage distance
- UV and tracking resistant (50+ years field installed)
- Lighter weight
- Bullet & impact resistant (reduced breakage)
- Hydrophobic (self-cleaning)
- Faster & safer installation (even on energized structures, since Vise Top Insulators eliminate wire ties)
- Compatible with all conductor types: bare and covered
- Environmentally friendly: 100% recyclable

Insulator failure

The electrical failure of insulators occurs either by puncture or excessive flashover.

When the arc passes through the body of the insulator, this can cause puncture, whereas flashover is caused by the arc discharging between the conductor and earth through the air surrounding the insulator. This is generally caused by line surges (lightning) or due to the formation of a wet conducting layer over the insulator surface. For satisfactory operation, flashover should always occur before puncture.

Reaction to lightning

Steep front lightning is the major cause of puncture failures in insulators. This is because, with a steep front wave, the voltage gradient does not have as much time to “stretch” across the rest of the insulator and it stays concentrated at the head and neck area – stressing the puncture value of the material.

Other findings in this area include:

- Standard 1.2 x 50 waveform mildly challenges insulators and typically will flashover every time.
- In recent 1.2 x 50 impulse testing of Class 56-1 insulators, the front was approximately 235 kV/µsec.
- In recent steep front impulse testing on polymer Line Post Insulators, the front range was 1800 to 2500 kV/µsec.
- 80% + of puncture failures occur in high lightning strike areas.
- Areas without severe lightning use 35kV insulators – i.e., Canada uses 35kV for the highway salt contamination

About Hendrix Molded Products

Hendrix is the originator of polyethylene insulators, and has worked to improve their design over the last 60+ years. Today, Hendrix is the leading designer, manufacturer, and supplier of high-density polyethylene insulators, with customers located around the world. Hendrix guarantees its core insulator products with a “Guaranteed for Life” program, offering 100 percent no-cost replacement if for any reason insulators fail in the field.