

# AC Testing Without Cable Degradation

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In addition to proof testing underground circuits, fault locating is enhanced with ac equipment.

**M**onitoring the integrity of cable insulation has always been a high priority among utilities because it ensures continuity of service for important underground circuits. The philosophy supporting proof testing is based on the premise that by detecting early insulation deterioration, remedial measures can be used when repairs are more conveniently and economically made. In this context, it has been shown that a failure caused during a test will cause less cable damage than a failure that occurs when the cable is delivering load.

Because ac testing has usually required bulky equipment, it has not been practical for testing moderately long circuits. As a consequence, dc testing has been employed because dc test equipment is almost trivial in size compared with ac test equipment. For example, a one-mile length of cable being tested at 50 kV ac would require test equipment with a capacity of between 400 kVA and 500 kVA. A dc test at 50 kV would require a capacity of only 50 W, using test equipment that is significantly smaller and easier to use than the corresponding ac test equipment.



Fig. 1. Vaughn Reigner, PECO Energy electric operations foreman, adjusts the equipment for a cable test. A high-voltage tank is in the background.

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## Differing Views on Proof Testing

There are opposing opinions about proof testing: some utilities have experienced increased service reliability as a consequence of routine testing while many utilities have experienced service failures attributed to insulation degradation caused by excessive proof testing. Proof testing can overstress the cable.

At PECO Energy, Philadelphia, Pennsylvania, U.S., cable failure that occurred soon after dc testing was considered to be indicative of unusual voltage stress caused by the dc potential. Consequently, dc hipot testing was avoided. In a program sponsored by the Electric Power Research Institute (EPRI) at Detroit Edison, there was positive confirmation that dc testing degraded insulation and affected the reliability of service-aged cables.

## AC Testing at Low Frequencies

The concern about overstressing cables during dc testing led PECO Energy to consider alternative test methods and, ultimately, the utility became industry advisors on a project at Cable Technology Laboratories of New Brunswick, New Jersey. Through its participation in this EPRI- and Canadian

Electricity Association-sponsored project, PECO Energy developed an awareness and interest in applying very low frequency (VLF) testing on its own system.

Prior to the research project, PECO Energy had designed and built a 60-Hz unit for fault locating and hipot testing. Since the primary application was fault locating, with a requirement for a capability of up to 40 A, 60 Hz, pulsed output, the primary voltage was limited to the relatively low level of 8 kV. A subsequent unit was built with a 15-kV output. Both units were successful for fault locating, but the drawback was that the output voltage was too low for a true hipot test and was insufficient to break down the cable after a circuit had tripped. The result was that dc testing was still necessary.

Because power cable systems are basically a capacitive load, the power necessary to energize them is proportional to the frequency. In the case of dc (where frequency is effectively zero), equipment is small in size; for ac, the test equipment is large. Each of PECO Energy's two 60-Hz test/fault-locating devices is mounted on its own large truck with the generator driven by an engine as large as 450 hp.

High Voltage Inc., Copake, New York, presented the possibility of performing hipot testing with a newly designed VLF model of test equipment, which would avoid the undesirable effects of dc. The equipment, compact and lightweight, is comparable in size and weight to a dc hipot test set. It is much smaller than a typical thumper.

The VLF sets produce a sinusoidal wave shape independent of capacitive loading and have user selectable frequencies of 0.1 Hz, 0.05 Hz and 0.02 Hz, with corresponding increasing capacitive loading capability as the test frequency decreases. This capability allows users to choose a lower frequency for longer cable lengths where 0.05 Hz may be used for lengths up to about 20,000 ft (6096 m), 0.02 Hz for longer lengths and 0.1 Hz for shorter lengths.



Fig. 2. A very low frequency 60-kV hipot set on a handcart sits next to a PECO Energy 60-Hz cable fault locating/hipot truck.

The 60-kV set, small enough that several are mounted on hand carts for easy portability, operates from standard 120-V receptacles.

PECO Energy has used the VLF hipot sets to proof test circuits after fault repair, to test new services prior to being energized and to test lines that have been out of service for several years and are being used again. Most of these older circuits are a mixture of cable types and can be tested at higher voltages with the VLF sets than is possible with the 60-Hz sets.

Since much of PECO Energy's cable work on extensions, rerouting and new circuits is performed by contract crews, the VLF sets are used to hipot all work as a quality control measure prior to acceptance. They have been successful in finding several splice problems that would have resulted in circuit failures if the system had been returned to service. They have also proven effective in finding several incipient 15-kV elbow failures during testing.

#### Fault Locating: An Added Benefit

After failure, some cable faults that were exhibiting a very high resistance would not break down because of the low voltage employed by conventional 60-Hz sets. In these cases, it was necessary to use high-voltage dc even though this method was avoided whenever possible. Where VLF sets have been used, their higher voltages have succeeded in causing breakdown in as short a time as one minute. The longest time to breakdown was 13 minutes. In these cases, the faults were sufficiently carbonized to allow the use of traditional

fault locating methods without continuation of the burning.

PECO Energy also has found that VLF has been more effective than dc in causing fault breakdowns on certain 15-kV, paper-insulated, lead-covered systems

and on 5-kV rubber and lead (R&L) cable that is used on service and main circuit taps. Failure mode of this cable often results in the conductor being burned back, requiring very high dc voltages to create flashover at the fault. The VLF sets are successful in causing fault breakdown on these R&L systems much more quickly, speeding fault location.

#### Conclusion

The EPRI- and Canadian Electricity Association-sponsored work performed at Cable Technology Laboratories demonstrated the ability of VLF testing to break down weak cables and not damage or degrade extruded cable systems. The use of VLF testing on PECO Energy's system has corroborated the results of the research and development effort. ■

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