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Failure Analysis on OPGW Cable During Short Circuit Test

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Abstract

A new type of ground wire used for communication lines in high-voltage power transmission systems is called Optical Ground Wire cable (OPGW). In addition to serving as a communication optical cable and standard overhead ground wire, it may also prevent lightning strikes and carry short circuit currents. The OPGW cable must fulfil the specifications for both construction and performance for the ground wire to work, the optical fiber integrity, and the optical transmission characteristics to be appropriate for the intended use. It is anticipated that OPGW cables will safeguard the optical fiber and that the cable's temperature won't rise to the point where the fiber's parameters could deteriorate. This paper examines the analysis and review of OPGW cable failure cases during short circuit tests.

Keywords: Bird Caging and Causes of Failure, Optical Ground Wire Cable (OPGW), Short Circuit Testing

1. Introduction

OPGW is among the most dependable fiber optic networks for telecommunication service providers, Internet Service Providers (ISPs), Cable TV providers, and other organizations involved in the provision of voice communications, data communications, video communications, text communications, conference communications, telemetering communications, etc. With the help of OPGW, power utility companies can now benefit from the special capabilities of a telecom carrier or service provider by enabling synergies between high-speed optical fiber-based Supervisory Control and Data Acquisition (SCADA) networks and efficient power distribution grids[1]. OPGW cable has the following advantages:

1. Fiber optic communication cables don't interfere with electromagnetic waves or cause any interference of their own.
2. System components can be electrically isolated from aerial fiber optic cables and any associated equipment.
3. The technology provides very long information transmission distances of up to 80 km without the need for repeaters.
4. The extremely high transmission capacity of fiber optic technology allows data to be transferred at up to three gigabytes per second (Gbps).
5. Acts as a conductive medium to transfer fault currents to ground and replaces a traditional ground wire, to shield the transmission system from lightning strikes.

When high heat dissipation requirements are met, the OPGW cable design is appropriate for high fiber counts. The cable is perfect for distribution transmission lines with shorter span lengths[2]. The OPGW cable construction must adhere to IEC publications 1396 and IEEE-P 1138. Optical fibers, which serve as the dielectric core of an OPGW, are shielded by an aluminium tube and covered in armour wires, typically composed of steel.

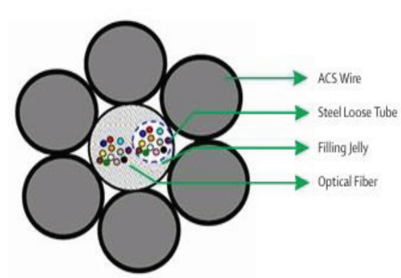

Figure 1. Single-layer OPGW cable[3].

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2. Design Requirements

Multiple buffered optical fiber units must be housed and protected from forces like crushing, bending, twisting, tensile stress, and moisture by the central fiber optic unit. Together, the outer stranded metallic conductors and the central fiber optic unit will function as an integral unit to safeguard the optical fibers against degradation brought on by ice loadings, vibration, lighting, fault currents, and environmental factors that could produce hydrogen. To house the buffered optical fibers, an aluminium rod that has been fabricated with one or more channels or grooves must be shaped into a helix. To provide an additional mechanical and environmental barrier, an outer protective shield, such as an aluminium tube or helically applied overlapping aluminium tape, must be applied around the rod[3]. The total OPGW's rated breaking strength must not exceed 90% of the total rated breaking strengths of each wire, as determined by their nominal diameter and the required minimum tensile strength. The optical unit's strength is not to be included in the rated breaking strength[2]. When calculating the composite conductor's total rated breaking strength, the fiber optic unit must be considered as a load-bearing tension member. OPGW must be located at the top of the EHV transmission line support structure; OPGW is susceptible to lightning strikes, galloping, and Aeolian vibrations. Ground fault current will also be carried by it. Its mechanical and electrical characteristics must therefore match or be comparable to those needed for traditional G.I. ground conductors[3]. On top of 400kV, 220kV, and 132kV transmission towers, OPGW will be installed. With extra guidelines and safety measures for handling fiber optic cables and live lines, the installation must generally follow the IEEE guide to the installation of Overhead Transmission Line Conductors[3]. The installation and long-term in-service exposure of OPGW cables to mechanical, electrical, and environmental loads must be tolerated without causing a noticeable decline in their performance[3]. To choose a suitable design, OPGW cable would have to meet certain fundamental performance requirements.

a. Electrical Performance

a) Fault current performance to address system imbalances or line-to-tower short circuits.
b) Lightning performance to prevent lightning arcs from compromising the cable's long-term functionality.

b. Mechanical Performance

a) Sag and tension
b) Vibration
c) Sheave and galloping

c. Environmental Performance

a) Range of wind zones and temperatures
a) Levels of corrosion at installation sites, including pollution levels[1-4]
a) Salinity ranges

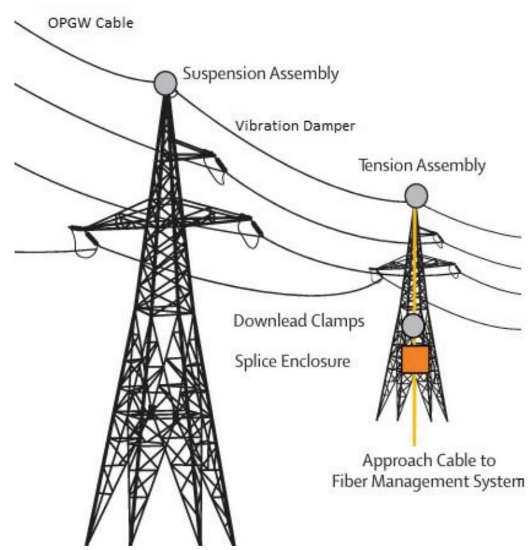

Figure 2. A transmission line with OPGW cable[3].

The potential for excessive contact pressure beneath hardware, the hardware's ability to transfer current when connected to the OPGW cable, and contacts between dissimilar materials that could lead to excessive corrosion in specific environments should also be considered.

3. Accessories of OPGW Cable

All necessary fittings and hardware are included in the installation of the optical cable. The general specifications for design, materials, dimensions and tolerances, corrosion protection, and markings as outlined in IEC 61284 must be adhered to by the OPGW hardware fittings and accessories. Every Holt must have a shear strength that is at least 1.5 times greater than the maximum installation torque. The fittings and accessories listed here are representative of the installation hardware commonly used in OPGW installations.

3.1 Suspension Assemblies

Armour rods made of aluminium alloy and performed armour grip suspension clamps must be utilized. The suspension clamps must be built to support a minimum of 2 5kN of vertical load. According to type test procedures, the suspension clamp slippage should occur between 12 kN and 17 kN in terms of measurement. The assembly's design must ensure that the conductor's and the OPGW's directions of operation coincide. The assembly's intended length must not violate the electrical clearance between the live conductor and the OPGW[5].

Figure 3. Suspension assembly[5].

3.2 Dead-End Clamp Assemblies

Every dead-end clamp assembly must have an executed armoured grip type and come with all the hardware needed to fasten it to the tower strain plates. Dead-end clamps must prevent cable cutting and enable continuous passage of the OPGW through. At least 95% of the OPGW's rated tensile strength must be the slip strength[5].

3.3 Clamp Assembly Earthing Wire

To earth suspension and dead-end clamp assemblies to the tower structure, an earthing wire measuring 1500 mm in length and having an equivalent size to the OPGW is required. The earthing wire needs to have lugs installed permanently on both ends. The tower structure at one end and the clamp assembly at the other are where the lugs are supposed to be fastened[6].

3.4 Suspension Towers and Tension Towers

Two parallel slots for the OPGW, one on either side of the connecting bolt, must be present in the clamp assemblies used to fasten the OPGW to the structures. When only one OPGW is installed, the clamps must be designed so that the clamping characteristics are not negatively affected. The OPGW will be located inside the tower by the tower attachment plates, which will be fastened to the tower legs and cross-members without the need for drilling or any other structural adjustments. Each suspension/tension tower should have an assembly of clamp assemblies and earth wire for attachment[5].

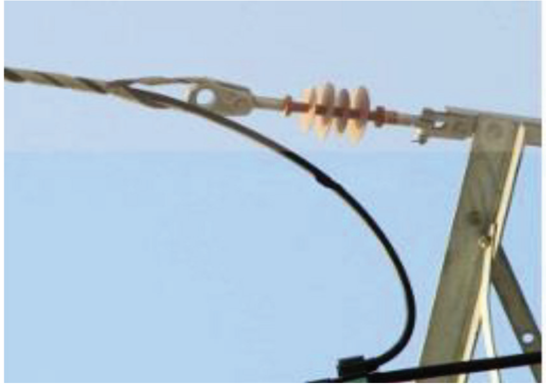

Figure 4. Tension assembly[5].

3.5 Vibration Dampers

For suspension and tension points in each span, vibration dampers of type 4R Stockbridge or an equivalent with four distinct frequencies dispersed throughout the Aeolian frequency bandwidth must be utilized. Should one be necessary, the designer will conduct a thorough vibration analysis to ascertain the precise number and location(s) of vibration dampers. Aluminium or aluminium alloy vibration damper clamps are used to support the dampers during installation and keep them in place without causing fatigue or harm to the OPGW. To lessen clamping stress on the OPGW, armour or patch rods made of aluminium or aluminium alloy must be supplied as needed. The body of the vibration damper must be made of permanent mould cast zinc alloy or mild steel that has been hot-dip galvanized[6].

3.6 Short Circuit Test

The purpose of the short-circuit test is to apply short-circuit conditions to the OPGW cable. Bird caging, tensile strength loss, and the melting or softening of non-metallic components due to extreme heat can all cause damage to the cable strands. Short-circuit conditions can also hurt the optical signals. The purpose of the short circuit test is to confirm both the optical and mechanical performance of the OPGW cable under the prescribed short circuit conditions.

Figure 5. Vibration damper[5].

After that, the cable will experience five official pulses. The lowest and maximum values for the electrical parameters for the official pulses are Fault I^2t, which is the minimum kA^2/s that the supplier specifies, and Fault Duration, which is the same as the primary protection breaker operation if that is known[4]. Else, no more than 0.5 seconds. Reaching the I^2t level for every pulse is the goal. The following accommodations are made to acknowledge the practical challenges involved in administering this test. The supplier's minimum I^2t level must be exceeded by the average of the five pulses. But no single pulse can fall below 95% of the required minimum I^2t level. Throughout the test, the optical sample will be visually inspected for bird caging and other damage regularly. Following the last pulse, the thermocouple with the highest reading must stay at the reference temperature for at least 15 minutes before the optical and temperature data are collected again. At this point, final optical, temperature, and cable observations will be made. Every cable component that can be separated must be done to check for signs of wear and tear, discolouration, deformation, and other problems[4].

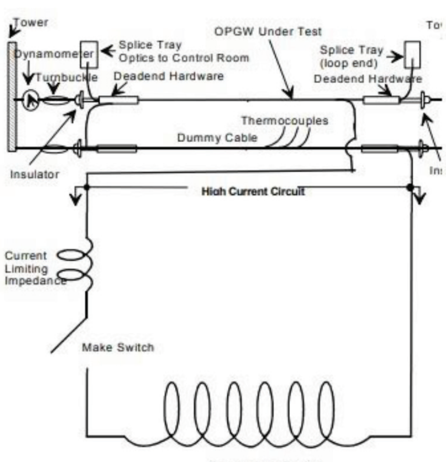

Figure 6. The electrical circuit for short circuit test[4].

4. Test Results

The OPGW Cable is examined in this study about axial and radial forces. Several noteworthy instances of experiments with short-duration current conducted at the Central Power Research Institute are presented.

Case study 1: An OPGW cable short circuit test was performed. To test the OPGW cable, a test current of 18.45kA was applied for one second. Figure 7 illustrates that during the fifth short circuit test, the OPGW cable was open circuited for 0.54 seconds.

Case Study 2: Short circuit test carried out on OPGW cable. 6.33kA for a 1-sec test current should be applied on the OPGW cable. During the test, a significant occurrence of arcing was observed on the OPGW cable. Subsequently, the OPGW cable is isolated from the test circuit at 0.62 seconds at the second short circuit test as shown in depicted in Figure 8. After the test wear and tear were observed on OPGW cable at the place of arcing.

Case Study 3: An OPGW cable short circuit test was conducted. The recommended test current for the OPGW cable is 6.33kA in one second. Following the fourth test of short circuit, bird caging was detected on the OPGW cable. Hence, further tests were discontinued.

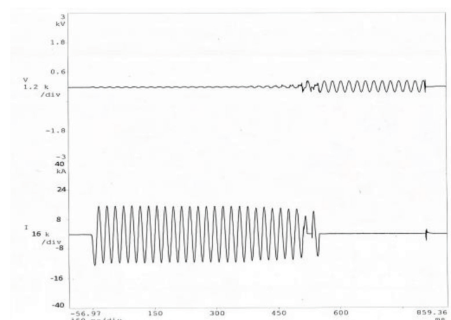

Figure 7. Oscillogram of OPGW cable.

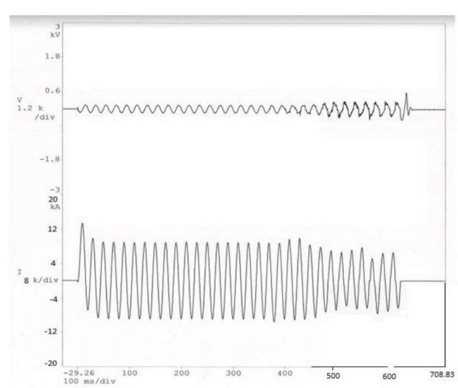

Figure 8. Oscillogram of OPGW cable.

Communication via optical fiber embedded in the ground conductor over the transmission line has entirely replaced SCADA and substation-to-substation communication. The selection of materials and the construction of OPGWs should be thoroughly examined from the outset of the design process, with consideration given to local environmental factors, conditions related to short circuit faults, and the implementation of all necessary precautions to avert potential issues. Zinc-sleeved steel stranded wire or aluminium-clad steel wire is used for the outer strand material. Steel is difficult to erode at high temperatures because of its high melting point. Steel has a high tensile strength. Therefore, even if some erosion does form, it is difficult to stretch and break under normal tension.

5. Conclusion

Depending on the conductor's design, the conductor's maximum temperature during and after a short circuit may vary. The optical fiber's parameter may deteriorate when the conductor reaches its maximum temperature. Therefore, to evaluate performance, a short circuit test on optical fibers embedded in the conductor is required. To increase the cross-sectional area of the strands and decrease the likelihood of strand breakage, use outer strands with a larger diameter. The choice of OPGW Cable should also take the fault current's magnitude into account.

6. Acknowledgement

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