A review on the application of fiber optics on high voltage lines

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Abstract: - In the new environment of energy and telecommunication markets liberation the infrastructure of the future with a unique electric network covering both needs in electric power and telecommunication services is developed. In this unified market fiber optics cables are designated to play a very important role. A review on the types of fiber optic telecommunication cables that are applicable on high voltage power lines is briefly presented in this paper. Optical Ground Wire (OPGW), Optical Attached Cable (OPAC) and All-Dielectric Self-Supporting cable (ADSS), for overhead power lines as well as fiber optics application in the construction of underground and submarine high voltage power cables are described. Electrical and mechanical parameters as well as availability and reliability matters are discussed, which in combination with environmental, financial and life cycle assessment issues determine the selection of the appropriate type for each case.

Key-words: High voltage line, Fiber optics, Telecommunication, Cable, Overhead power line

1 Introduction

Electricity Utilities need light current networks for their own operational and administrative requirements. New schemes of distributed (or dispersed) generation from small scale power producers, like renewable energy sources, contributes to a rising complexity of power networks with control necessities that result in increasing application, development and utilization of telecommunication networks. Deregulation of electricity market, has as consequence greater flexibility in the reaction of power utilities to adopt new technologies and methods that may reduce operating costs and improve their business performance. So, more sophisticated and efficient schemes are considered for control, protection, monitoring, metering and data acquisition.

Telecommunication infrastructure that integrates operational and commercial services is a must for power utilities nowadays. Many power utilities are forced to invest in new telecommunication assets for their own needs; so they obtain valuable experience and a reliable infrastructure that can be used as well for new trade prospects. This is a reason for power utilities entering a new market, the telecommunications market, asking for a share of this fast rising commercial market.

Furthermore, scientific estimations consider that the electric network of the future will distribute both energy and information, covering both needs in electric power and telecommunication services. In the formation of the new infrastructure of this unified market fiber optics cables is expected to play an important role.

There are important motivations for power utilities to entry the telecommunication market. The most remarkable of them can be classified in the following three categories:

- Simultaneous lliberalization of both the electricity and the telecommunication markets
- Customers already connected to the power network
- Increasing telecommunication needs that create demand for extra capacity and new opportunities from fiber optics technology

The last mentioned developments in fiber optics technology can offer solutions for their application on high voltage AC power lines that can meet safety, cost and quality requirements necessary either for power or for telecommunication services. Such technical solutions in the technologies of fiber optics

incorporated in high voltage AC lines will be reviewed in the following.

2 Technologies of fiber optics incorporated in high voltage ac lines

The main medium for reliable transmission of information nowadays is fiber optics. The progress in the fiber optics technology worldwide is greater than the estimated, generating related advantages. The main benefits over the coaxial or copper wire media as well the radio links, which constitute the optical transmission as the best choice in power utilities, are the following:

- Enormous potential bandwidth
- Low transmission loss
- Small size and light in weight
- Signal security
- Electrical isolation
- Immunity to interference and crosstalk

The high voltage AC lines consist of overhead conductors, submarine and underground cables. As a consequence, the technologies of fiber optics built-in at high voltage AC lines are the:

- Fiber optic cables for high voltage overhead lines
- Fiber optics incorporated in submarine cables
- Underground fiber optic cables.

The overhead lines represent the main backbone system of the power company, while submarine and underground cables complement the range of the available technologies, especially at the end points of the overall network.

2.1 Overhead lines

Among many types suitable for different applications on high voltage overhead lines the most important are the following:

- Optical Ground Wire (OPGW)
- Optical Attached Cable (OPAC) and
- All-Dielectric Self-Supporting cable (ADSS).

2.1.1 OPGW (Optical Ground Wire)

The OPGW is a composite conductor where optical fibers are coexisted with the metallic groundwire. The optical components are contained within the strands of the groundwire. The OPGW cable replaces the traditional groundwire and is totally self-supporting. Once installed the OPGW covers the dual performance functions of a standard ground conductor with telecommunication capabilities. A number of design options due to the different structures and forms of the fiber optic unit are available such as loose tube type or tight buffer type, metallic or plastic tubes and helically stranded or single tube, which have slightly different performance. The OPGW in Fig. 1 represents the most common available construction.

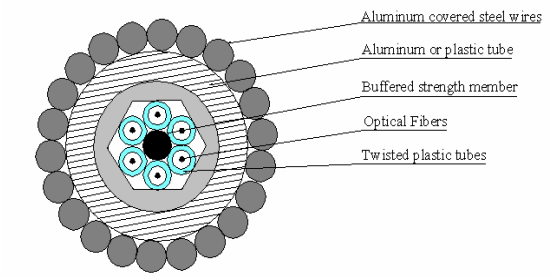


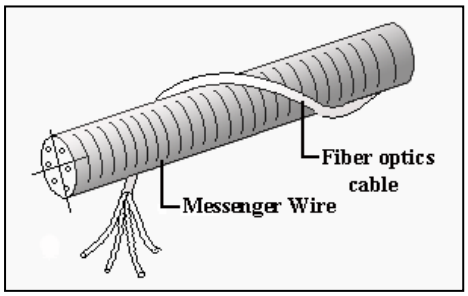
Fig. 1. Indicative cross section of OPGW for the application of fiber optics on H.V. lines

2.1.2 OPAC (Optical Attached cable)

The attached cable technology is characterized by the differentiation of the fiber optics telecommunication cable from the high voltage conductor. The latest is carrying the fiber optics cable, which is attached on it. This technology provides a suitable means of retrospectively deploying optical cable along an existing power line route. Three different types of attachment can be applied, characterizing the technologies as the preform attached by clips or clamps, the wrapped and the lashed cables [2]. The cables are small, all-dielectric and flexible. The most frequent type, a fiber optic cable wrapped helically around the earth or phase wire of an overhead power line and its cross section, as well as a lashed one, are illustrated in the Fig. 2. Since the conductor around where are wrapped supports them there is no obligation to have considerable strength in the cable. Different types of sheath materials are used to withstand

bird attacks and electric fields induced by the phase conductors.

a



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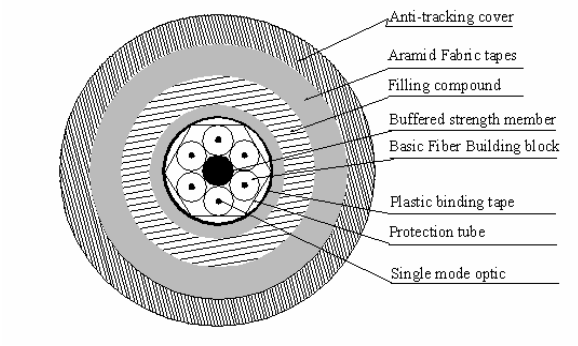

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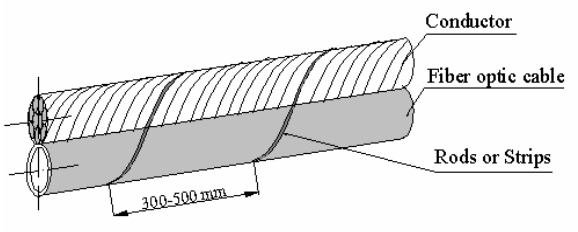

Fig. 2. Attached cable technology.

a: Composite wrapped aerial cable

b: Typical indicative cross section of attached aerial wrapping cable

c: Fiber optics cable lashed on earthwire of a high voltage line

2.1.3 ADSS (All Dielectric Self Supporting)

The self-supporting cables are fixed to the transmission tower structures in such a manner that are separate from the conductors providing independent communication paths. For this purpose, the power system structures must be robust and safe to support the additional load. As, it does not contain metallic elements, polymer yarns from aramid or glass reinforced plastic rods ensure its mechanical performance to tensile strength. In the design illustrated in Fig. 3, loose tube buffered optical fiber cable and glass fiber reinforced plastic rods are stranded together inside the outer sheath.

2.2 Submarine cables

The submarine cables are used to connect the island network with the main power energy network, to cross lakes and rivers, across harbors or between landmasses and sometimes carry a great amount of traffic. To anticipate damages that may caused by ships anchors, fishing trawls, seawater pressure etc, the cables are constructed with special protective layers, such as steel wire armor layers and bitumen coatings, as it shown in Fig. 4. Lead sheath covers seal the underwater cables hermetically. Composite constructions contain up to 36 fibers in the space between phases, operating with 1550 nm wavelength transmission, are offered for medium voltage applications and are available at 90 km unrepeated section lengths [3].

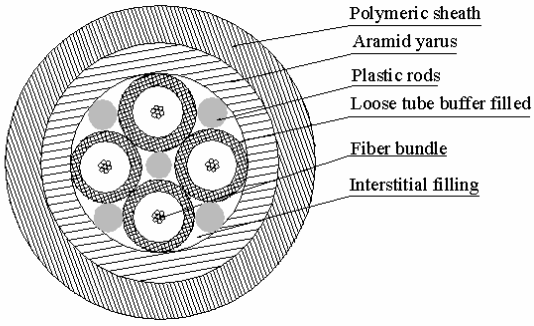

Fig. 3. An example of a composite self-supporting aerial cable.

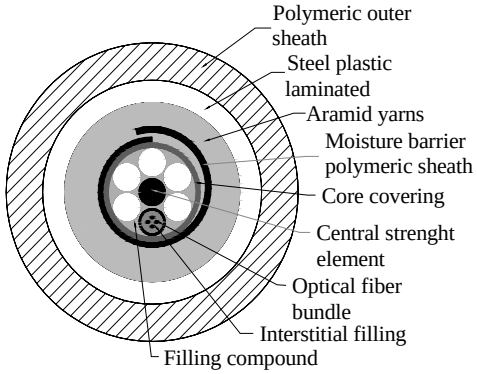

Fig. 4. A typical composite medium voltage submarine cable

2.3 Underground cables

The underground cables are usually used inside cities or at the termination positions of the overhead lines, consisting the final link drop to substations. The underground cables are either buried directly in the ground or are housing in existing ducts, water pipes or troughs. Since the undergrounds are open to a number of eventually damages, special protection is needed during the fabrication and the installation stage. The strength members are metallic or dielectric and the most common types include steel wires armor, aramid, reinforced polymer rods and corrugated steel tapes within the cable. The metallic steel tapes furthermore provide protection of moisture and rodents. Additionally, some layers of water blocking materials provide the water penetration protection. For this purpose petroleum gels, grease and compounds that swell and absorb the humidity are used. Special jackets and steel or brass tapes are used for the underground fabrication to protect against termites and rodents attacks respectively, as it illustrated in Fig. 5. In regions with high lightning activity it is advisable to use non-metallic elements to avoid induced currents damages [4].

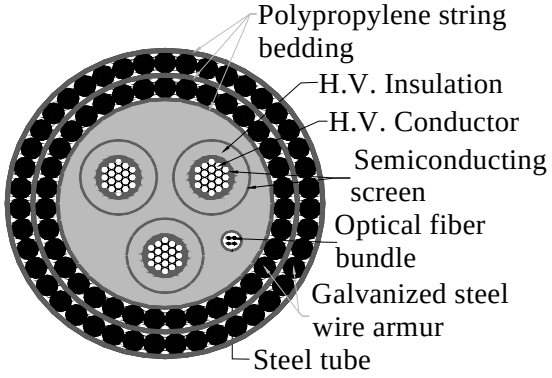

Fig. 5. Underground direct buried cable

3 Selection of the appropriate fiber optics technology for high voltage power line applications

Each high voltage power line has its own constructional, electrical and environmental characteristics. The selection of the appropriate type of fiber optic technology for each case of high voltage power line is a complex procedure. The main parameters which should be considered for the installation of an optical cable for a specific application are the following:

- The electrical parameters of the power line, i.e. nominal voltage, level of the short circuit current, fault correction and protection time for a short circuit to ground, line impedance, possible induced voltages, etc.
- The mechanical parameters of the power line, i.e. the mechanical condition of the conductors, the need to stand additional loads and their supporting infrastructure, the configuration of the poles, towers and the suspension points, the maximum endurance to mechanical stress effects, etc.
- Transmission characteristics of the optical fibers like bandwidth, attenuation, dispersion, etc
- Environmental issues, such as temperature ranges, risk of lightning, wind speed, solar radiation, surrounding environment and electromagnetic compatibility
- Financial parameters including further to the initial cost, the cost of maintenance and the life cycle assessment [5].

It is to be noted that power companies are not constrained in the usage of only one specific type of optical cable. In several cases, especially when the network is gradually expanded, like in the cases of fiber optics applied on the protection system, different types of optical cables may be used in the same network. Anyway, fiber optic cables and the associated fittings have to be tested, to verify their compliance with the established standards, in order to guarantee that the electrical, mechanical and optical integrity of the cables will maintain during the predicted duration life.

4 Discussion and conclusions

A brief review on the types of fiber optic telecommunication cables that are applicable on high voltage power lines has been presented. Optical Ground Wire (OPGW), Optical Attached Cable (OPAC) and All-Dielectric Self-Supporting cable (ADSS) have been examined, for overhead power lines

application. Furthermore, the application of fiber optics in the construction of underground and submarine high voltage power cables has been described.

All the above mentioned cables have different optical characteristics, performance and operating conditions and can implement in various environments, but all fabricated to meet the requirements for telecommunication services provided with great availability and reliability. The electrical and mechanical parameters of the power network and environmental and financial issues, as well as their life cycle assessment determine the selection of the appropriate type for each case.

Energy and telecommunication markets liberation offer the framework where a new infrastructure mode is formulated. In this infrastructure of the future, a unique electric network will distribute both energy and information, covering both needs in electric power and telecommunication services. In this unified market fiber optics cables are designated to play a very important role in the formation of the new electric network infrastructure.

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