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Effectiveness of Fiber Optic Cable Technology in Domestic Communications

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Abstract:

From time to time technology has tried to design and improve commucation system ,the development of the field communication demand very easy and rapid transmission of data over long distance. consistent domestic communications are essential to ensure safety, security and control of the power system equipments. Such communications customarily have been provided by methods such as power line carrier and microwave radio systems but are more recently being supplemented or replaced by Fiber optics. This paper focuses on the practical steps to review and evaluation on the effectiveness of using Fiber optic cable technology in the domestic communication of power system network. With the advent of information and communication technology, it has become obvious that Fiber optic is replacing this crude method of data communication. It offers a unique solution to ever increasing demand for bandwidth because of its remarkably high capacity for carrying data, and guaranteed consistency of signal transmission over the entire transmission network. A pair of Fiber has the ability to carry over eight thousand simultaneously voice channels and has high immunity to electromagnetic interference. All these advantages made it extra-ordinarily useful in data communication like Internet, multimedia and scads applications. Over short or long distances, video, audio and data signals arrive at their destination in the same perfect quality as they originated and also assure security of data being transmitted.

Keywords:

Technology, transmission of data, Optical Fiber, Security, attenuation, Fiber degradation, bandwidth, splicing, Scads.

1. Introduction:

The explosive growth of information technology and broadband applications has been driving the strong demand for bandwidth in the telecommunications networks. Enabled by present Optical Fiber communication technology, Fiber Optics is emerging as the fastest and most cost-effective way to maximize and expand network capacity. In the last five years, the Fiber optic communications industry has experienced an unprecedented growth and rapid technological changes. Power companies are one of the biggest users of communications.

This is because reliable internal communications are crucial in Power Company to ensure protection and control of the power system equipments. If there is a poor communication path, there could be false information or no information transmitted from the control centre that informs the operators and consumers about the status of their equipment in the network. The computers (servers) that control the application software are stored in the control room at the Power central office locations or headquarters.

With some of these applications, the operators may offer to host the software equipment at their site or a remote site in which the utility will have access to obtain their information. This allows the operators to maintain the servers and support all the software applications such that the application runs properly. This communication technique offers a variety of advantages that are suitable for electrical companies to disseminate information within their network.

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The FOC Market:

Fiber optic technology and wireless data communication systems are becoming a necessity in many residential and commercial projects across the globe. It's the evolution of the market and as the options keep getting more and more advanced, realtors are keen on offering 'futuristic' products to their clients. Today, several initiatives promise to make fiber to the building (FTTB) more economical to deploy and better positioned to meet even the most aggressive bandwidth demand forecasts. Telecom cables are required across the backbone, aggregation, and access networks. Fiber to the premises (FTTP), fiber to the home (FTTH), and fiber to the building (FTTB) applications are some of the key factors driving the demand for the FOC industry worldwide.

Need for High Speed Connectivity:

The increasing need for 24x7 high-speed connectivity and increased traffic generation from voice, messaging, emails, games, downloads, mobile internet access, video streaming & other services have unleashed the benefits of optical fiber cable networks.Recognizing the need for high speeds and 24x7 connectivity, there has been a conscious effort to make the telecommunication network robust, future proof and reliable. FTTH/FTTB has been introduced in India and is a fast growing phenomenon for a robust telecom network. India's fixed broadband user base grew by 24.5 percent in 2011 to 13.3 million, up from 10.7 million at the end of 2010. India is set to become one of the Top 10 largest fixed broadband markets in the world during the course of this year (it is currently 11th). The Fixed broadband market is set to grow to approximately 49.3 million subscribers in 2015. The market for fixed broadband equipment is expected to increase by a Compound Annual Growth Rate (CAGR) of 13.6% from 2010 to 2015. However, the overall Broadband penetration in India is very low when compared to developed countries. India had only 13.95 Million broadband connections in April 2012 against the target of 20 Million by 2010. Address this issue of connectivity,

India's Fiber Manufacturing Capability:

Though the market consumption over the last two years has not lived up to the demand projections, Indian fiber manufacturing capacity is on the rise with over 30 Mn km/ year. Also, capacity for FOC manufacturing in India is over 8 Lakh Cable KM. Thus, India can domestically meet the requirements for the upcoming OFC projects. Sourcing fiber optic cable from domestic manufacturers, will not only suffice upcoming projects' requirement for resources but in fact provide a great impetus on bolstering the domestic market, save on foreign currency, promote R&D, and provide high quality evolving products for an evolving Indian Information and Communications Technology (ICT) industry.

2. Fiber Optics:

fiber optics, also spelled fiber optics, the science of transmitting data, voice, and images by the passage of light through thin, transparent fibers. In telecommunications, fiber optic technology has virtually replaced copper wire in long-distance telephone lines, and it is used to link computers within local area networks. Fiber optics is also the basis of the fiberscope used in examining internal parts of the body (endoscopy) or inspecting the interiors of manufactured structural products.

The basic medium of fiber optics is a hair-thin fiber that is sometimes made of plastic but most often of glass. A typical glass optical fiber has a diameter of 125 micrometers (μm), or 0.125 mm (0.005 inch). This is actually the diameter of the cladding, or outer reflecting layer. The core, or inner transmitting cylinder, may have a diameter as small as 10 μm. Through a process known as total internal reflection, light rays beamed into the fiber can propagate within the core for great distances with remarkably little attenuation, or reduction in intensity. The degree of attenuation over distance varies according to the wavelength of the light and to the composition of the fiber.

When glass fibers of core/cladding design were introduced in the early 1950s, the presence of impurities restricted their employment to the short lengths sufficient for endoscopy. In 1966, electrical engineers Charles Kao and George Hock ham, working in England, suggested using fibers for telecommunication, and within two decades silica glass fibers were being produced with sufficient purity that infrared light signals could travel through them for 100 km (60 miles) or more without having to be boosted by repeaters.

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In 2009 Kao was awarded the Nobel Prize in Physics for his work. Plastic fibers, usually made of polymethylmethacrylate, polystyrene, or polycarbonate, are cheaper to produce and more flexible than glass fibers, but their greater attenuation of light restricts their use to much shorter links within buildings or automobiles.

The Physics behind Fiber Optics:

A fiber-optic cable is composed of two concentric layers, called the core and the cladding, as illustrated in Figure 3-1. The core and cladding have different refractive indices, with the core having a refractive index of n1, and the cladding having a refractive index of n2. The index of refraction is a way of measuring the speed of light in a material. Light travels fastest in a vacuum. The actual speed of light in a vacuum is 300,000 kilometers per second, or 186,000 miles per second.

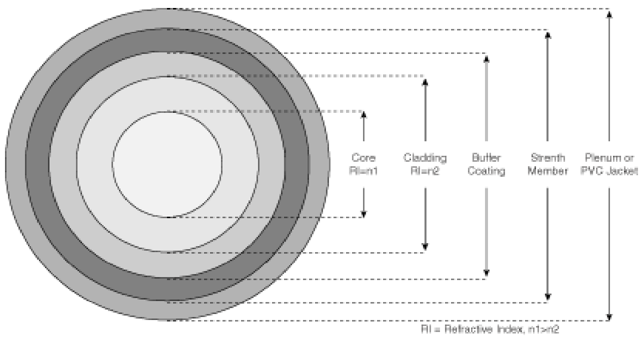

Figure 1: Cross Section of a Fiber-Optic Cable

The index of refraction is calculated by dividing the speed of light in a vacuum by the speed of light in another medium, as shown in the following formula:

Refractive index of the medium = [Speed of light in a vacuum/Speed of light in the medium]

The refractive index of the core, n1, is always greater than the index of the cladding, n2. Light is guided through the core, and the fiber acts as an optical waveguide. The propagation of light down the fiber-optic cable using the principle of total internal reflection. As illustrated, a light ray is injected into the fiber-optic cable on the left. If the light ray is injected and strikes the core-to-cladding interface at an angle greater than the critical angle with respect to the normal axis, it is reflected back into the core. Because the angle of incidence is always equal to the angle of reflection, the reflected light continues to be reflected.

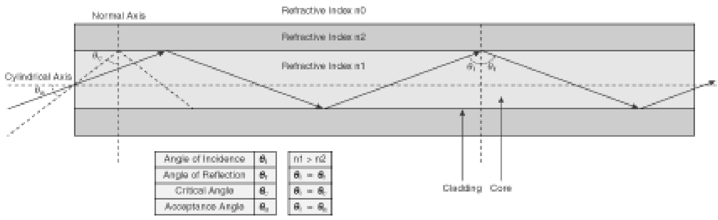

Figure 2: Total Internal Reflection

The critical angle is fixed by the indices of refraction of the core and cladding and is computed using the following formula: qc = cos–1 (n2/n1) The critical angle can be measured from the normal or cylindrical axis of the core. If n1 = 1.557 and n2 = 1.343, for example, the critical angle is 30.39 degrees. a light ray entering the core from the outside air to the left of the cable. Light must enter the core from the air at an angle less than an entity known as the acceptance angle (a): qa = sin–1 [(n1/n0) sin (qc)]

In the formula, n0 is the refractive index of air and is equal to one. This angle is measured from the cylindrical axis of the core. In the preceding example, the acceptance angle is 51.96 degrees.

The optical fiber also has a numerical aperture (NA). The NA is given by the following formula:

NA = Sin qa = square root of (n12 – n22)

From a three-dimensional perspective, to ensure that the signals reflect and travel correctly through the core, the light must enter the core through an acceptance cone derived by rotating the acceptance angle about the cylindrical fiber axis.

As illustrated in Figure 3-3, the size of the acceptance cone is a function of the refractive index difference between the core and the cladding. There is a maximum angle from the fiber axis at which light can enter the fiber so that it will propagate, or travel, in the core of the fiber.

The sine of this maximum angle is the NA of the fiber. The NA in the preceding example is 0.787. Fiber with a larger NA requires less precision to splice and work with than fiber with a smaller NA. Single-mode fiber has a smaller NA than MMF.

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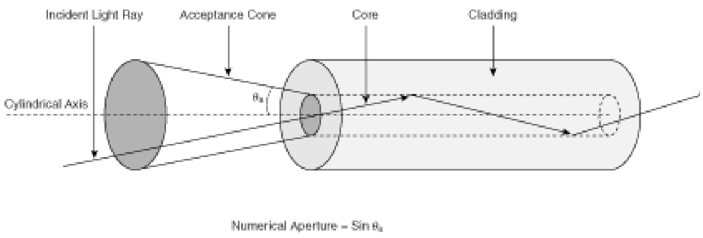

Figure3: Acceptance Cone Performance Considerations

The amount of light that can be coupled into the core through the external acceptance angle is directly proportional to the efficiency of the fiber-optic cable. The greater the amount of light that can be coupled into the core, the lower the bit error rate (BER), because more light reaches the receiver. The attenuation a light ray experiences in propagating down the core is inversely proportional to the efficiency of the optical cable because the lower the attenuation in propagating downs the core, the lower the BER. This is because more light reaches the receiver. Also, the less chromatic dispersion realized in propagating down the core, the faster the signaling rate and the higher the end-to-end data rate from source to destination. The major factors that affect performance considerations described in this paragraph are the size of the fiber, the composition of the fiber, and the mode of propagation.

3. Applications of Optical Fibers:

Optical fiber is normally used by many telecommunications companies for transmit telephone signals, cable television signals and Internet communication. Due to much lower attenuation and interference the optical fibers have large advantages over existing copper wire in high demand and long-distance applications. However, the infrastructure development within cities was relatively difficult and it is also time consuming, and fiber optic systems are quite complex and expensive to install and operate. Due to these difficulties, optical fiber also known as fiber optic communication systems has primarily been installed in long-distance applications. Normally these are used to their full transmission capacity and offsetting the increased cost. But now the prices for fiber optic communications have become quite less. And the price for fiber to the home has become more cost-effective than that of rolling out for a copper based network.

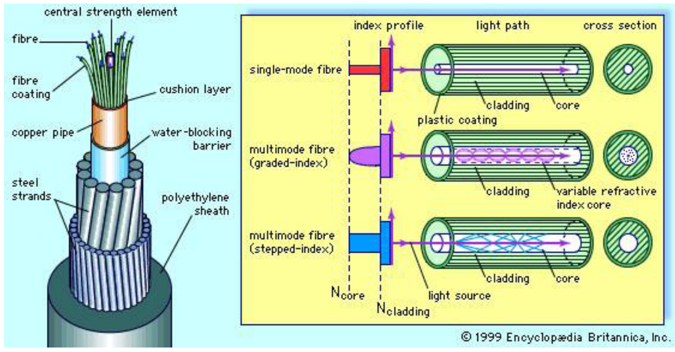

Figure 4: Encyclopedia Britannica

3.1. Methods Used In Overhead Distribution of Fiber Cable

ADSS (All-Dielectric Self-Supporting) is the simplest concept for aerial Fiber-optic cable: it is an underground Fiber Optic cable made stronger to allow it to be installed by attaching it to a series of poles. The cable needs to be physically strong because it will be supported only at each pole along the route and will have to support its own weight across the half-span on each side of the pole.

This is in contrast to an underground cable which is fully supported inside a duct or in a back-filled trench along its whole length. In addition to its own weight, ADSS cable must support the extra loads imposed by wind pressure and by the buildup of ice when this is problem in exposed locations. These extra loads can be significant and require carefully designed clamps to spread the mechanical strain over several meters of cable at each pole to prevent any risk of damage.

ADSS cables have the advantage that they are completely independent of the electricity supply network, even though they are installed on the same poles. Potentially the two networks can be owned, managed and maintained by different organizations, although there are safety issues when people carry out installation and maintenance work in close proximity to live electricity conductors.

3.2. OPPC (Optical Phase Conductor):

This is a replacement electrical conductor that has Optical Fibers built into it as part of the manufacturing process.

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The Fibers are inside the conductor, usually contained within a stainless steel tube. OPPC is installed on an overhead electricity line in place of one of the normal conductors. OPPC replaces one of the normal conductors and therefore it adds nothing to the appearance of an overhead line and it does not affect the mechanical or electrical rating of the line. From this point of view, OPPC is the least obvious and most secure of all of the cable types.

However it is also the technology that is most intimately associated with the electricity supply network as it physically forms part of this network. Any maintenance activity on either the communications or power network involving OPPC will have an impact on the operations of both networks. OPPC is normally only installed as part of the construction of a new line or during the complete refurbishment of an existing line and so it is unlikely that OPPC will be specified by any organization other than a power company.

3.3. Access Wrap:

This is a technique that installs a Fiber-Optic cable onto an overhead electricity distribution line by wrapping it securely onto one of the power conductors. This is a scaled down version of the Sky Wrap process that has been used since early 80s to install Fiber-Optic cables onto power transmission lines; the smaller, lighter Access Wrap machine is designed to work on power lines supported by wood or concrete poles and with conductors spaced only 0.5m apart.

The optical cable is supported by its host conductor and so it does not need to carry any of its own weight. Therefore it can be very small and this means it has little effect on the mechanical and electrical performance of the overhead line; it also has little impact on the appearance of the line. Installation is carried out using a special device which travels along the host conductor carrying a drum of Optical Fiber cable.

The device rotates as it moves and wraps the cable under carefully controlled tension onto the host conductor at a pitch length of about three quarters of a miter. Clamps are used on each side of each pole to hold the cable in place on the conductor. The machine moves at about walking pace with about 15 minutes

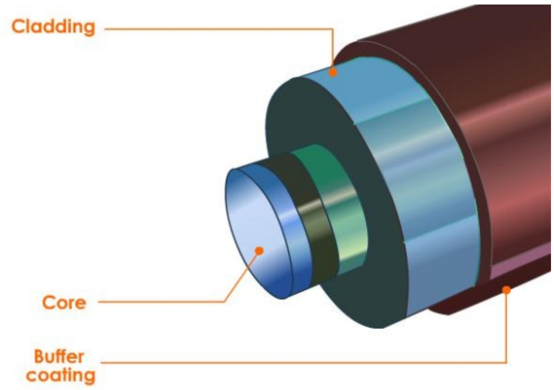

Figure 5: Attenuation in Fiber optics

Optical Power:

Optical power measures the rate at which electromagnetic waves transfer light energy.
Optical Power P = dQ / dt
Where P = optical power (watts)
dQ = instantaneous charge (joules)
dt = instantaneous change in time (second)
Optical power is generally stated in decibels relative to a defined power level, such as 1 Mw (dBm) or 1uW (dBu). Mathematically stated
dBm = 10log[P (watts)/0.001watts]
dBµ = 10log [p (watts)/0.000001watts]

Advantages:

» The key advantages of using overhead electricity distribution lines to carry cables providing broadband connectivity can be summarized in three distinct areas: speed, security and cost.

» **Speed**: It is always much, much quicker to install Fiber-Optic cable by attaching it to poles than it is to dig trenches to bury it underground. Directional drilling or sloughing are alternative ways of installing underground cable, but these are also slow and expensive compared to installation on overhead lines.

» **Security:** This is a key concern in any Fiber-Optic cable installation. Cables have been installed on overhead power lines since the very early 1980s and have developed an excellent reputation for security and reliability over that time. Power utilities use these cables to carry critical communications for control of the electricity network.

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» **Cost:** The higher unit cost of aerial cables compared to underground cables is more than offset by the much lower cost of installation and therefore aerial cables have the lowest total cost.

4. Literature Review:

The fastest means of carrying information would be the use of fiber optic networks. This offers the transmission of data from one location to another. Fiber optic is an optical tube cable that is designed to transport data threw glass over an optical light. An optical light has the capability to travel at a distance of 126,000 miles per second within an optical fiber. There are many components that make up the fiber optic cable.

The first section of the cable is the optical fibers. The optical fiber is the component that actually transports the data in the fiber optic cable. The optical fiber component is made up with three different parts: the buffer coating, the cladding, and the core. The buffer coating, which is the outer portion, provides the cable its strength and support in that helps prevent the cable from breaking. The cladding and the core both are designed to help enhance the transmission of the optical signal. The second section of the fiber is designed for the outdoor environment. Many cables have different designs, but for most cables today they are designed with a Kevlar portion that helps add extra strength to the cable.

4.1.Three Basic Parts of Fiber-Optic System:

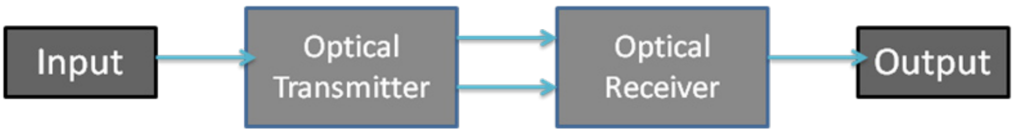

Figure 4: Generic Optic communication system

Transmitter:

The transmitter unit converts an electrical signal to an optical signal. The light source is typically a light-emitting diode, LED, or a laser diode. The light source performs the actual conversion from an electrical signal to an optical signal. The driving circuit for the light source changes the electrical signal into the driving current.

Fiber-optic cable:

The fiber-optic cable is the transmission medium for carrying the light. The cable includes the Optical Fibers in their protective jacket.

Receiver:

The receiver accepts the light or photons and converts them back into an electrical signal. In most cases, the resulting electrical signal is identical to the original signal fed into the transmitter. There are two basic sections of a receiver. First is the detector that converts the optical signal back into an electrical signal. The second section is the output circuit, which reshapes and rebuilds the original signal before passing it to the output. Depending on the application, the transmitter and receiver circuitry can be very simple or quite complex.

5. Electrical Modeling And Analysis:

Electric field modeling and analysis of OPGW and the WRAP Fiber optic cables is not typically required beyond traditional analysis normally performed for regular ground wires. However, in unusual situations in which ground wire corona occurs, WRAP aerial cable placement can be analyzed using a 2-D electrostatic analysis.

Detailed 3-D modeling and analysis of electric field patterns near the structures are recommended in order to identify locations that will minimize the electric field induced degradation of ADSS aerial cable. Otherwise, catastrophic failures within a short period of time (2 to 10 months) can result. However, 3-D analyses require significant resources which may not always be available prior to placement of aerial optical cables and wires. At a minimum, a 2-D space potential calculation should be used to identify the most suitable placement location for standard and angle suspension structures.

At the same time, it should be realized that a more rigorous 3-D analysis may allow the placement of ADSS cables in potentials up to 40 kV (i.e., calculated in a 2-D analysis) by considering the shielding effect of the transmission structure.

5.1 Fiber Preparation:

Fiber Striping:

Optical Fiber must be stripped of buffer coatings to allow a closer fit within precision connectors. (Note always wear safety glasses or goggles when working directly with fibers)

Mechanical Stripping:

Buffer coatings are usually removed mechanically with sharp blades or calibrated stripping tools. In any type of mechanical stripping, the key is to avoid nicking the fiber.

Splicing Optical Fiber:

Preparation of fibers for splicing is very similar to the process described under connecterization. After jacket materials, strength members and buffer tubes have been cut to the appropriate lengths, the fiber buffer coatings must be removed.

Cleaving:

After the buffer coatings have been removed, fibers must be cleaved in preparation for splicing. Cleaving is a method of breaking a fiber in such a way as to create a smooth, square end on the fiber.

5.1.1. Fusion Splicing:

Fusion splices are made by positioning cleaned, cleaved fiber ends between two electrodes and applying an electric arc to fuse the ends together. A perfusion arc is applied to the fiber while the ends are still separated to vaporize volatile materials which cause bubbles. Final precise alignment is done by moving fiber ends together until there is slight pressure between end surfaces. An ideal fusion cycle is short, ramped cycle is short and uses ramped or gradually increasing arc currents. A short ramped cycle is considered least likely to produce excessive thermal stress in fibers. Cold temperatures is require increased time and arc current Experienced operators consistently produce fusion splices with loss less than 0.2 dB per splice and averaging 0.3 dB on multi mode fibers Sophiscated fusion splicing systems for single mode fibers produce typical splice losses 0.05 to 0.1dB.

5.1.2. Mechanical Splicing:

This splicing systems positions fiber ends closely in retaining and aligning assemblies. Focusing and collimating lenses may be used to control and concentrate light that would otherwise escape. Index matching gels, fluids and adhesives are used to form a continuous optical path between fibers and reduce reflection losses.

5.2 Optical Power Measurement:

When optical fiber has been installed, all splices made and connectors attached, it must be determined if the system is capable of delivering the required power. The simplest test require light source of same type wavelength and approximate power as that equipment to be used. The system equipment itself is often satisfactory source. The first step is to obtain an approximate measure of system launch power. A short test cable with same fiber and connector style as the installed cable can be used for this procedure. One end of the short cable is connected to the light launching equipment. The other end is connected to an optical power meter. After the initial readings taken on short length of test cable, a second similar reading is taken with the installed cable place. The difference between the two readings indicates the additional power losses due to fiber length differences in optical qualities of connectors.

Optical Power Meter:

Power meters often read directly in power units such as dBM and dB. By using connector adapters and light sources of the same wavelength as installed equipment, an accurate measure of link losses with connectors and splices may be obtained.

5.3 Optical Time Domain Reflect meter (OTDR):

OTDRs are typically used to measure distance and attenuation over the entire fiber link. They are also used to identify specific points along the link where losses occur, such as splices. An OTDR is optical radar which measures time of travel and return strength of a short pulse of light launched into an optical fiber.

Small reflections occur throughout the fiber, becoming weaker as power levels drop distance. At major breaks, large reflections occur and appear as strong peaks on oscilloscopes. Testing of short and medium distance fiber optic systems seldom requires an OTDR. In smaller systems, optical power meter tests are faster and more useful. Many instrument rental companies are now offering OTDR as well as other fiber optic splicing and test equipment.

5.4. Inspection Methods and Tools:

ADSS aerial cables require special safety precautions as a result of their possible semi- conducting nature. Special safety procedures and arrangements need to be defined to inspect ADSS aerial cables whenever working under live line conditions. While ADSS cables can be considered non-conducting during the installation in the presence of live lines (i.e. if regulations allow), ADSS is very likely to become semi-conductive during the service life as a result of surface deposits and the hydrophilic nature of the jacket material, which should be considered during maintenance. Equipment required for inspection and maintenance for ADSS, OPGW, and WRAP aerial cables and wires is usually limited to technology that can be used to check for the integrity and degradation of the transmission in the fiber of the communication cable. Currently, there are no inspection tools (i.e., other than close-up visual examination)

6.Conclusions:

This paper, discussed an Optical Fiber cable in domestic communication of power grid network as an alternative media installed to the power line carrier and microwave radio to enhance adequate and efficient communication and security in the grid. The use of 132 KV power transmission line infrastructures between the Optical networks can satisfy present need of high speed and reliable data, video and voice communications from all existing equipments, offices, operators, and maintenance engineers and technicians. Primarily, there are three different cable options available to electric companies that opt to integrate communications into their existing power transmission system. The currently available cables and wires that can be used in high voltage passages are:

ADSS (All-Dielectric Self Supporting Cable) OPGW (Optical Ground Wire) WRAP (Optical Cable Wrapped on Ground Wire)

Future expansion of the network to include all other 132 KV and 400 KV substations have been taken into account in the design work. Extra Optical Fibers in the OPGW are reserved for future use to connect all towns the network pass through or pass by. And the people living in these towns will be served when the future expansions are implemented. The issue of security power network Inspection and damage assessment tools need to be identified to evaluate the integrity and confidentiality of aerial cables and wires. These inspection and assessment tools are required by electric utilities to locate developing problem areas prior to catastrophic failure. Regular inspection and reliable damage detection procedures and tools could be used in preventive maintenance programs that could significantly reduce repair cost and increase the reliability of the communication system.

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