OPGW Installation Manual

Contents

I. Introduction

1. It becomes essenstial to learn some about regular methods and practical directions about how to set overhead OPGW optical cable. These methods and directions can be flexibly chosen according to the local conditions, client's requirements and preparations in each installation.
2. Before installation, client must regularly acquire a table with the data of sag and tension of OPGW optical cable included.
3. The OPGW optical cable can be installed almost in the same way as the power line wire is done. Please refer to "*IEEE Guide to the Installation of Overhead Transmission Line Conductors*", ANSI/IEEE 524-1980 for detailed explanation about various installation techniques. However, special attention should also be paid to its differences from the installation of ground transmission wire.
4. Required Equipments:

Items	Descriptions	Specifications	Units	Quantity	Comments
1	Tension Machine	3．5T	unit	1	The diameter of tension wheel must be 60 times bigger than that of optical cable. Better to equip with a tension display
2	Coil Rack	with brake	unit	1	Better to be supported by anchors on both sides
3	Cable-towing Machine		unit		
4	Haulage Cable		KM		straight wire with no twist
5	Haulage Cable Rack		unit		
6	Bending-resistance Connector		unit		fixed by steel wire
7	Rotary Joint		unit	2	3T
8	Wringing-Resistance Rope		piece	1	
9	Steel Ground Tackle		piece	1	
10	Ground Tackle		piece	2	
11	Line Tackle		piece		Diameter is over 600mm
12	Terminal Tackle		unit	2	Used at the first tower
13	Lever Block	3T	piece	3	
14	Gripper		piece	3	
15	Rubber Tube		meter	20	

16	Wire tightener		piece		Pre-twisted tension wire is required
17	Torch Wrench		piece	6	
18	Ground Anchor	Large	piece	6	
19	Walkie-talkie		unit	12	
20	Rope		Meter	250	

II. Preparations Before Installation and for Optical Cable Inspection and Acceptance

1. Before optical cable is inspected and accepted, cable coils and external rings of optical cable should be carefully checked. The check must be focused on whether there are blind bends and corners in the internal sides of optical cable during loading. The optical cable must be extended to be checked whether some undiscovered damages or depressions are potential on the external stranded wires and whether some “birdcages” exist in the whole cable coil.
2. Before installation, all the required data must be tested and compared with that provided by supplier to find out whether they are different.
3. The road where optical cable will be laid must be checked and cleared of any obstruction. A single coil of optical cable must be ensured with no more than two angles of 90 degrees or four angles of 45 degrees.
4. Although the mechanic strength of OPGW optical cable is very high, the cable can be still damaged due to incorrect installation. The cables should be kept from twisting together and have its dynamic bending more than 40 times as long as the cable diameter. In the installation, a 600mm bending radius must be guaranteed at least while the cables should not be twisted at the same time. Any damage will affect the service life and performances of optical cable.
5. Before installation, any obstruction should be removed from the road to ensure the future installation unaffected. During installation, the external stranded wires should be kept away from any damage. Before installing optical cable, the workers in charge of installation should be trained and taught about the properties of optical cable, such as minimum bending radius and the differences between optical cable and electrical cable, optical cable and overhead conductor, etc.
6. While the installation is done on a street or highway, someone must be appointed to guide the traffic and prevent from any accident. Principally, the method of tension stringing should be employed in the installation of OPGW optical cable because it can keep the cable in a certain tension and suspended. It can prevent the surface of optical cable from dropping on the ground and getting damaged. In the meantime, it can reduce the compensation for crops and speed up installation.

   If any long span or crossed block appears, nets and cords and other supporting things will be put in the span under control or other precautions should be taken when the stringing tension is higher than the required 20% RTS.
7. Similar to the installation of electric power line, the electric power for original line should be

shut off during installation and the installation should not be executed in bad weather, such as strong wind, snow and rain, etc.

8. The related operation regulations in the system of electric power should be complied with. Only special hardware, clamps and devices are used to tighten OPGW optical cable. Pre-twisted wire is required to be used in this project in order to increase force bearing area as well as friction force and reduce the movement of external stranded wire.

10. When the installation must pass through any intersection or cross over any highway, optical cable must be overhung to a safe height in order to keep vehicles from crashing into or running over it, which will endanger the cable and people.

11. Before installation, cable laying tower and collecting tower should be connected to ground wire or ground protection is used on the cable laying pulleys and the cable collecting pulleys, in order to keep a safe installation.

III. Equipments, Methods and Cautions for Installation

1. A lower cable laying tension can help with the maintenance and service life of optical cable and the safety of this cable laying system. It can keep the line from slanting and help OPGW against shakes. Furthermore, it has slightly pressed on the optical cables on the pulleys in the first tower and terminal tower. While setting a tension machine, the leading rope against ground should form an angle of less than 30 degrees, or in the distance 3 times as far as that between tension machine and the first tower. The overhead heights of OPGW are presented as below:

   Unmanned Areas: OPGW is 3 meters high over ground.

   Walking Roads and Roads with Little Traffic: OPGW is 5 meters high over ground.

   Highways and Railways: OPGW is 7.5 meters high over ground.

2. The coil rack must be designed to bear forces in order to prevent optical cable from some external forces. Anchor is buried in earth deeply and its accessory wire should be strong enough. Its berm must be in the direction of force. Special workers must be appointed to dig holes and bury anchors in the ground steadily. A sinking proof layer must be reserved. Anchor piles are added to the anchors that are buried in soft earth. While unloading cable coils, it is necessary to start removing the packing boards from two sides. It is forbidden to do it from the middle as it may damage the external stranded wire of optical cable.

3. Reel winder and tray tractor can be employed in the installation of OPGW optical cable. However, the leading and braking system should be kept in a steady operation in case sudden halt or jerk happens during laying cable. In some sections with many corners and complicated routine, the hauling speed is better to be kept below 20m/minute.

4. Selecting pulleys: the diameter of those pulleys at the pull-in and pull-out points should be no less than 800mm or that of fixed multiple pulley blocks. The internal grooves of those pulleys should be covered with an elastic buffer layer of neoprene. The pulleys at suspension tower

or crossing points should have their diameter no less than 600mm. At least, the pulleys at two hauling ends should be connected to ground together with the tower.

5. Hauling clamp: the net clamp with rotary joint is used to haul optical cable and prevent it from twisting during the process of hauling as best as possible. Meanwhile, the clamp can be used to adjust the arc sag of optical cable. Before the net is put on, it must be checked whether its size matches with the external radius of optical cable.

6. As "primary elongation"(or optical cable strain) exists during the arrangement and installation of OPGW optical cable, the cable should be installed according to the sag 12 to 25 degrees lower than that in the data sheet of sag and tension. And when there is no wind or ice, the span between the lowest point of sag and conductor must be kept: $S \geq 0.012L+1(m)$ L is the span.

四. OPGW Installation

1. OPGW optical cable can be installed almost in the same method of tension wire-laying as employed in the installation of electric power line. However, attention must be paid to that its tolerant minimum bending radius is routinely 40 times as wide as the diameter of optical cable.

2. The method of "backward hauling" is frequently used in the installation of OPGW optical cable, and very suitable to install the high-voltage electric power supply line over large spans and the lines over many obstructions. Beforehand, all tie-ins can be connected to OPGW that will be leaded by the removed old ground wire. Old ground wires can be replaced by untwisted wires in order to have a reliable and rapid hauling. The procedure is presented in detail as below:

(1) Cable coils are set and fixed on tension wire-laying racks or tackles and imposed with certain tension so as to prevent them from spinning too fast.

(2) A tension device should be set on where cable coil is located.

(3) The hardware fittings are arranged on the suitable height of tower. The pull-up and pull-down rods must be set on the metal accessories of every supporting tower at ends and cut-line areas.

(4) Pulleys are set on every supporting tower and optical cable is installed below or above metal accessories.

(5) A thin control wire will pass through the pulleys on every supporting tower and lead the hauling wire back through every transmitter from where tension starts. After passing through the first span, the hauling wire will go around OPGW optical cable and metal net.

(6) As OPGW optical cable can be divided into several sections and then leaded through the whole transmission system, it should be adjusted to keep its minimum load after leading through the first section.

(7) After optical cable is laid, its sag, tension and supporting hardware fittings should be adjusted and installed as required along every span from its ends.

(8) While skipping, preformed armor rod is added before tightening one end and a 5-8mm span should be left between the stranded wires in the hardware fittings at two ends, in order to prevent the slightly sagged optical cable from fractioning against metal tower.

3. Cautions During Installation

According to the system design and the parameters of related equipments, the connecting location, pull force, tension and supporting point can be determined and variously affect the loading on tower. As the service life of optical fiber is an important property of electric power optical cable, it becomes the most important to maintain the service life of optical fiber. The service life of optical cable is related to something as below:

$$t_s = t_r \quad (\sigma_r/\sigma_s)^n\{[1-Ln(1- F_s)/ N_pL]^{(n-2)/m} — 1\}$$

In the formula: F_s——optical cable fracture probability

N_p——the number of breaking area in each mile during the process of selecting tension (in the worst condition)

L ——standard section length

σ_r——selecting tension (g);

σ_s——the tension burdened by optical fiber as optical cable is pulled in a long term (g);

t_r ——tension selection endurance time (s);

t_s——service life of optical cable (s);

n ——static fatigue factor;

m——Weibull slope distribution.

According to the above formula, the inverse relation can be formed between the service life of optical fiber and the length of each electric power optical cable as well as the tension during installation. In other words, the electric power optical cable should be prepared in an acceptable length during installation and maintenance when the cable is put on coils. We suggested its length is best around 3KM. Moreover, we must take into account the inverse relation between the tension and cable life while the long-term operation tension (or equivalent to installation tension) of electric power optical cable must be selected. In order to increase the service life of optical cable more effectively and reduce its wear-out coefficient, the safety coefficient of optical cable can be increased to a certain extent as the installation tension of optical cable are limited in a suitable range. At present, some designs for electrical power optical cable are only concerned with stress-strain curve and inappropriate span limitation (lowest sag of electric power optical cable is normally higher than conductor to keep a safe distance over objects). In these designs, their installation sag is small and the installation tension of optical cable has been 20% higher than its nominal tensile strength. They do not take into consideration the properties and materials of optical cable, so that their designs may reduce the service life of optical cable. In this case, we had referred to foreign materials and suggested that the installation tension (long-term operation tension) is better to equal to 16-18% of the nominal tensile strength of optical cable.

(1) Any twist is not allowed to happen when optical cable is transmitted through chutes. If optical cable is found to twist in the same direction, the leading should be halted immediately and then the tension is released and pulleys are rearranged.

(2) As leading machine and tension machine are both set on towers, they must be limited in a force bearing range of 20% breaking force. Cable coils should be arranged on the straight line between two first towers, in order to prevent optical cable from twisting or damaging its external cover.

(3) The strength of anchor and supporting tower hardware fittings should be over the maximum loading of optical cable, with a safety coefficient added. The value of safety coefficient must depend on the current operation process. When wind vibration is employed, the safety coefficient, as required, should be increased to a certain value to compensate for the reduced strength of hardware fittings. While some tension are imposed on sage of optical cable, we are required to temporarily add to tower with pull-down rod and anchor to prevent the tower from losing balance. It is considered best that the pulling rods have a minimum slope of 1/2. The type of anchor should meet the requirements of earth and loading. When the installation of optical cable starts, all pull-down rods should have their tension adjusted suitably or re-added.

(4) Optical cable must be overhung above the minimum length when it traverses roads, railways and other electric power conductors.

(5) The cable hauling speed can be controlled around 20m/minute and kept steady during the process of hauling. At the same time, the maximum hauling tension should not be overtaken.

(6) In order to make it easy for cable connection and the adjustment of cable sag, excess cable should be reserved to allow the cable connection to be done on the ground.

(7) The back-twist and looseness of OPGW can easily cause twisted wire to hunch, damaging the excess optical fiber in the cable. Therefore, one or two twist proof whip(s) with a 5m torque can be added and very useful to avoid the “birdcage” phenomenon. Twist removing machine must be used at two ends.

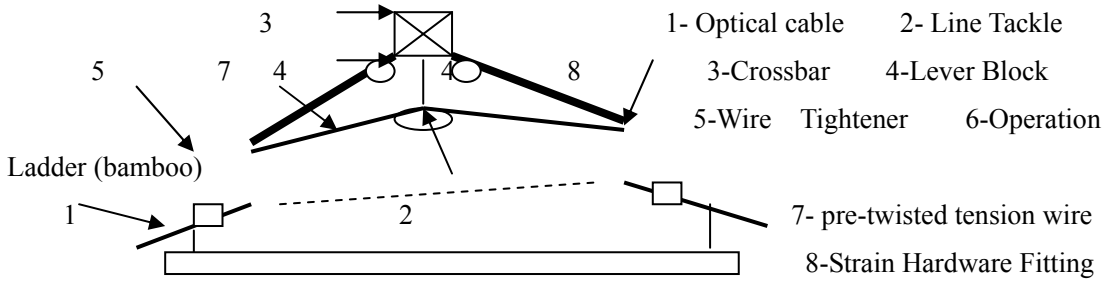
（8）During installation, external twisted wire must be carefully protected because aluminum alloy can carry electrical current and attract lightning strike and its damage will be a long-term hidden trouble for the whole line. Pulleys must be checked whether any burr exists. Optical cable should not be thrown carelessly. While using wire holder, rubber tube should be used to protect optical cable.

V. Optical Cable Clamp Components and Installation

1. Hardware fittings used in the installation of OPGW optical cable usually include static end (strain), overhanging (cut-line), damper, lead-in clamp and ground wire, etc.

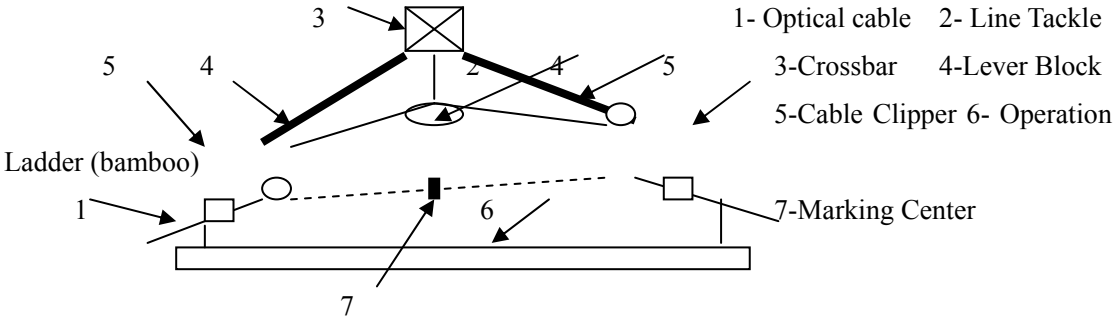
2. Static end (strain) clamp is used at the ends of optical cable or tower that forms with the line an angle more than 30 degrees (15 degrees at each side). Its basic components include

structural enforcing layer (pre-twisted wire), clamp, U type loop and an adjusting pull-tab that has a more than 0.15mm negative tolerance at the diameter of optical cable.



Drawing for Installing Accessories of Tension Tower

3. Overhanging (cut-line) clamp used at tower that forms with the line an angle more than 30 degrees (15 degrees at each side). Its basic components include structural enforcing layer (pre-twisted wire), external twisted wire, rubber insert, case and hanger, etc.



Drawing for Installing Accessories of Straight Tower

4. Static End (strain) clamp Installation Procedure

(1) Pre-twisted wires are tied up by a color strip at an end to form a bunch that will be put around optical cable. The color strip can be used as a kind of positioning mark. All the other pre-twisted wires are also put around the cable and they reel together very tightly in the end in order to cover all the equipments. Their ends must be arranged very tidily. Any tool should not be used to cut them from upside as it may damage optical cable.

(2) The color marked place on pre-twisted wire is matched with the colored point on static ends clamp and about 50 cm of its one side is winded. U type ring must be put inside the hollow loop and adjusted to fit better in it by moving bolt. The color marked place on the second static ends must be targeted to the colored point of the first static end that has been partially around pre-twisted wire layer. The second static end should also be circled around the external side of pre-twisted wire layer at the same length 50cm. Later, the rest part of static ends should be fully circled around the pre-twisted layer while the two ends of pre-twisted wire layer are bounded by tape. All the pre-twisted layers are fixed.

(3) U type ring is fixed to expansion control loop that will be put on the tower.

5. Overhanging Clamp Installation Procedures

(1) A color mark exists in the middle of pre-twisted layer and a supporting wire is arranged in the middle and spiraled down to two ends. Each supporting wire will be added nearby the positioning color mark that is particularly used as the supporting wire for pre-twisted layer.

(2) Rubber insert is put on the middle color mark of the arranged pre-twisted layer. The seams around case must be kept horizontal and adhesive strip is around the middle part of insert to keep it from moving.

(3) As the middle of pre-twisted layer is over the insert, two entwined wires are positioned on both sides of the insert and bended to the same extent as the insert is.

(4) Around the insert, other wires are added and should not be entwined with each other. They should run parallel with the insert and have two ends neat. Please note that no tool is used to cut them off on the top.

(5) Two halves of AGS case should be arranged on the two sides of assembly center. The AGS splint must be settled in the right place and then tightened by a bolt passing through its middle hole. It should not be fixed too tightly as its AGS case may be jammed. Overhanging loop or fixings.

(6) Overhanging loop or fixings are connected on the tower.

6． Special Ground Wire

The system is grounded to leave a way for short circuit current. It is achieved by a certain length of twisted aluminum wires to and well connected to hardware fittings and metal towers. Its installation torch is 15N·M. As the parallel groove clamp can be directly connected with optical cable, it is suggested to use it in order to ensure the good connection between optical cable and grounding system.

7．Shock Absorber

Shock absorber is currently a kind of widely used accessory for shock preventing. It can be positioned more than 50cm away from twisted wires in the hardware fittings while its low frequency maul should face its head toward tower. During installation, the torque wrench is used to prevent optical cable from bearing too much side pressure and its value must range around 8-12N · M.

VI. Sag and Tension

Sag is normally measured in the isometric testing method by means of the binding sag board or in the varying length testing method with a theodolite due to different angles. The sag is generally measured at somewhere overhead not far away from ground and with a representative span.

1． After optical cable is installed over each span, sag and tension should be adjusted. The order of adjusting sag and tension of a span usually from one end of the system to another end. The general optical cable sag is measured along the whole optical cable line from the cable spinner. The construction sag of OPGW cable should rely on its tension. Therefore, the sag and tension of the optical cable between tension towers must be decided on topography and

required headroom. If the headroom distance is below the required one, tension can be increased to reduce sag. In the meantime, the reduction of sag will increase the tension of optical cable. Therefore, the supplier's OPGW optical cable must be tested whether it meets the requirements for this span.

2. Terminals: enough optical cable is hauled into the generator room and ensured to arrive at terminals and with enough excess for future connection.
3. erminal tower: pull-down clamp should be employed to fix the optical cable pulled down from tower.
4. The loose excess cable must be moved and set on the tower among spans and unnecessary imposed with press or even tension. In order to make room for the temporary static end leading clamp, the loose excess cable is essentially moved in this way. After the loose optical cable is removed, the tension machine is started in the inverted direction to pull optical cable back to the cable coil. At this time, tension should not overpass half of maximum installation tension.
5. Loose cable is removed to make room for temporary static end components a distance 1.5-2 times as long as the length of static end assembly (about 2-4 meters). Before installing the permanent static end components, tension adjusting clamp should be used to maintain the sag and tension among spans. As for towers and temporary static end, a set of equipments connected to tension adjustment, including a chain winder, dynamometer and large size of chains. After referring to the sheet of sag and tension, the loading is added and the tension among spans started to be adjusted.
6. Generally, the order adjustment is required to go toward where cable coils are arranged one span after another. The tensions in several spans can be adjusted at the same time, even if several towers are existing in a series of spans. After the span tension is adjusted, overhanging and straight hardware fittings in a span can be installed while temporary static ends can be connected to towers in one time. When too large spans appear in the tension adjustment on temporary static ends, the adjustment devices must be moved more often and cost a longer time.
7. After the above procedures are done, permanent static ends can be overhung and how far the colored band away from expansion control loop, inserted U type ring and static end hollow loop can be measured. All the results will be recorded and used as reference to determine whether permanent static ends can be installed there. As soon as the span tension is adjusted, the reference distance between the span and tower should be measured. From this point, structural enforcing layer (pre-twisted wire) is set and colored band is put at the measured place on the optical cable. Once static ends are installed and hardware fittings are connected to towers, the tension on the tension machine can be released and temporary static ends can be removed. When permanent static ends should be installed on the nearby span, the expansion control loop can be set under the static ends to help bend optical cable and keep its

minimum bending radius, which means the shaped optical cable must located 14 inches lower than the cable rack. The procedure will be repeated till sag and tension are adjusted for all the spans in the whole system.

VII. Line Signal

Some striking signals should be used to differentiate optical cable from electrical cable. These signals have two main functions or targets: one is to provide the directions of optical cable for the line maintenance while the other is to prevent it from being stolen. The tags with non-metallic optical cable or protection cable can be hung at somewhere more striking.

VIII. Data Storage

1. Suggestions for files: it is suggested to record and put in files all the following materials in every system of optical cable

(1) Key maps: A key map refers to one geological drawing that contains the relationship between the routing of this system and roads, it and highways. It is intended to provide rough locations for us to find out some crucial areas in the system, for instance, connecting points and where it crosses over main roads. The units (meter) of length must be put down on the drawing in order to help find out connecting points and its intersections with roads and rivers.

(2) Coil Distribution Chart: It is a linear chart to demonstrate the order of cable coil distribution by the number of cable coils as well as marks for the lengths (meter) of major construction places, such as connecting places and major road intersections. The length of every cable coil in each section and the total length of optical cable should be marked on the chart. Meanwhile, types and quantities of optical cable and optical fiber should be marked on every section of cable coil.

(3) Construction Form: this form must present actual equipments in every tower, as well as other materials about the tower types and specifications, the total distance from tower to each end and other details about connection to ground and connection shield. In these forms, the construction details can help correct and adjust any change happened in the installation.

(4) Line Form: it contains the line, system and quantity of optical fiber and the important results of repairing the buffer

(5) Testing Record Sheet (Form): it records the output power, input power and the attenuation level tested in the case of receiving. The OTDR curves or pictures of each optical fiber and terminal pigtail should also be recorded in this sheet, which are acquired by inputting lights of 1310nm and 1550nm wavelength from two directions. It is suggested that other materials should include the average bidirectional loss at every connection and the pigtail continuous loss containing the loss of inserting a connector.

(6) Materials proved by supplier: They conclude the data sheet of every coil of cable, the electrical field strengths between different types of towers, suitable places for optical cable installation as well as a chart of sag and tension.

(7) Annual System Checking: After a cycle, the attenuation of this system will be identifiable, steady and different from that in a test. It is suggested to find out reasons if the attenuation has gone on seriously and even endangered the safety and reliability of communications.

After the optical cable line installation is finished and accepted, it becomes important to collect and store all kinds of materials. These materials include (1) key map that demonstrate the direction of optical cable in this line, (2) all kinds of forms used in the installation, (3) layout and powerhouse distribution drawing that are generally provided by measure and design company, (4) it is also essential to acquire the data sheet of optical cable and the sheet of sag and tension that are provided by supplier and fulfilled with installation tension, operation tension and short circuit current, etc. (5) the records of annually checking the attenuation of system, and so on. If the loss is changing at 1dB/km, all the parts in this system should be carefully checked.