

OPGW Installation in Energized Transmission Line

Fumitaka Nishimura, *Member, IEEE*, Liliane D. Cicarelli, *Member, IEEE*, Ruby Rudy Arellano and
Maurício R. Soares, *Member, IEEE**

Abstract -- Although the installation of OPGW (Optical Ground Wire) in existing transmission line has often been carried out by power transmission companies worldwide, power system operators has been imposing restrictions to the planned outages of the transmission lines. Because of this, the Power Transmission Companies have opted for the OPGW stringing with energized transmission lines. A quite safe and productive methodology called “Carrier” was adopted[†]. The method consists in using a self-propelled carrier that slides on existing grounding wire, while pulling an aramid rope and positioning several double pulleys. The OPGW gets strung by pulleys and then replaces the existing ground wire. This paper describes the experience of several OPGW stringing, including methodology and tools used, advantages and main results achieved. Additionally, it shows how team training was conducted and security measures undertaken.

Index Terms -- Construction Works for Transmission Line; Energized Line; Ground Wires; OPGW Cable; OPGW Installation in Alive-Lines; Overhead Transmission Lines.

I. INTRODUCTION

The stringing of OPGW (Optical Ground Wire) in existing overhead transmission lines (OHTL) have been often used in many Brazilian power transmission companies. In the conventional method, the replacement of an existing ground wire by OPGW required planned outage of the transmission line. However, the electric system operator imposes a series of restrictions to disconnect the transmission lines. For that reason, transmission companies have opted for OPGW installation in energized transmission lines.

In order to avoid disconnecting lines while meeting the transmission companies’ needed to replace the existing ground wire by the OPGW, a very safe and productive energized line methodology called “Carrier Method” has been applying[†].

The goal of this paper is to describe the experience of many OPGW stringing projects with energized power lines of different voltage classes (138 kV to 750 kV), performed during the last 6 years. The paper describes the methodology and characteristics of the lines, tool specification, work teams, training, safety practices as well as productivity, improvements through the method and main results.

* F. Nishimura (e-mail: fnishimura@procable.com.br).

L. D. Cicarelli (e-mail: lcicarelli@procable.com.br).

R. R. Arellano (e-mail: rubyrudy@procable.com.br).

M. R. Soares (e-mail: mosoares@uol.com.br).

All with PROCABLE Energia e Telecomunicações Ltda.
Avenida Casa Grande, 1960 – Diadema, SP - CEP 09.961-350
BRASIL – Phone: (55)11-4061-9101.

[†] The “Carrier Method” was developed by Fujikura Ltd, Japanese cable manufacturer, and with the partnership of Procable Company the methodology was improved to Brazilian transmission line characteristics.

II. CARRIER METHOD DESCRIPTION

A. Procedure

The “Carrier Method” is a construction method for stringing OPGW cables in overhead transmission lines with totally energized circuits. The method uses a self-propelled carrier, which slides over the ground wire to be replaced (Fig. 1). The self-propelled carrier can be operated by radio remote control and it can use a video camera for cable inspection.

The self-propelled carrier pulls a high tensile strength specially insulated wire, highly resistant to mechanical impact loads and to electric tracking and positions several pulleys (Fig. 2), every 15 to 20 meters away from each other.



Fig. 1 - Self-propelled Carrier

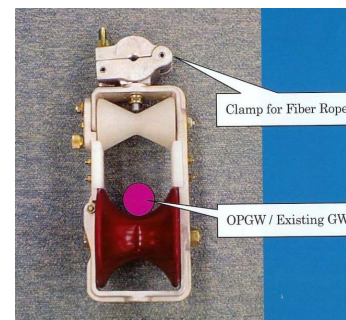


Fig. 2 – Double Pulleys

Once the rope is tensed in one reel length (average 5 km, with 10 to 15 towers) and the pulleys are positioned, the existing ground wire is loosened. By tensing the rope, the pulleys turn 180°, inverting the position of both rope and existing ground wire. The rope then stays on top of the existing ground wire.

Next, the OPGW is connected to the ground wire and the latter is pulled with the puller. During the pulling, reinforcements are made on the ground wire repairs with repairs rods. This pulling lasts approximately 2 hours and requires electricians placed at the towers at the ends of the reel and at three or four intermediate towers.

Finally follows the regulation and clamping of the OPGW cable.

B. Preparation

Before locating the carrier and stringing the rope and the OPGW, it is necessary to prepare the local, placing the materials and tools on a bag located next to the tower foot. There shall be an area isolated by fence to prevent unauthorized people from accessing the work site (Fig. 3).

The puller, the tensioner and the drum stand shall be located in the appropriate positions.

To have an effective communication system, a radio shall be placed on the puller, on the tensioner and into the vehicles. Additionally, portable radios shall be used by the work team and the linemen who will remain on the towers during the OPGW stringing.



Fig. 3 – Puller and Work Site

C. Steps

The installation method consists of the following six steps [1]:

- 1) Step 1 – Deploying the double pulleys
- 2) Step 2 – Tensioning the aramid fiber rope
- 3) Step 3 – Stringing the OPGW cable
- 4) Step 4 – Tensioning the OPGW cable
- 5) Step 5 – Removing the rope and pulleys
- 6) Step 6 – Clamping and Sagging the OPGW

D. Advantages

The advantages of this method are:

- Low mechanical tension in the OPGW cable required during the installation. The typical stringing tension is 300 daN;
- Minimizing of installation sag.
- Clearance between ground wire, phase conductors and OPGW can be kept in safety distances.
- The overload due to the carrier, pulleys, rope and OPGW cable does not affect the existing ground wire since the load is distributed along the ground wire by the pulleys.
- This method is the safest and most productive, particularly for EHVTL, for example, 500kV and 750kV.

III. TOOL SPECIFICATIONS

The following special tools and equipments are used for the Carrier Method.

Other types of hardware, used in conventional method and Carrier methods, are not described in this paper.

A. Self-propelled Carrier (Fig. 1)

Used for the aramid rope stringing, it runs on a diesel motor. It weighs from 35 to 40 kg and has a speed of 15 to 30 m/min on the grounding wire. When specified, the self-propelled carrier can be remotely controlled via radio and can also use a video camera to inspect the condition of the ground wire.

B. Aramid Fiber Rope

Essential component of the methodology, the rope must be insulated, with low humidity absorption, low elasticity module, high mechanical resistance and high resistance to electric tracking. The rope used is made of aramid coated with polyethylene, with a nominal diameter of 14mm, weight of 0.160 kg/m and mechanical resistance of 9,000 daN, suiting works up to 750 kV.



Fig. 4 - Counterweight Tail Device

C. Vertical Double Pulleys (Fig. 2)

The pulley for OPGW cable and aramid rope stringing, installed along the ground wire, is made of aluminum with 2kg nylon pulley blocks.

D. Curve Pulley Block (Fig. 5 e 6)

Installed on the towers, for 90° angles, its has a steel articulated framework with 5 or 6 aluminum pulley blocks and weighs 45 kg.

E. Single Pulley Block (Fig.7)

Installed on the towers, made of aluminum alloy, they have two types: 1,000 mm (40 kg), for structures at the ends of the reel and 650 mm (23 kg), for structures in between them. Those pulleys are equipped with a sliding device (aluminum pulley block), for the continual grounding of the ground wire (GW) and OPGW cables.

F. Counterweight Tail Device (Fig. 4)

A steel counterweight tail flexible device of approximately 1,000 mm to 1,300 mm length (8 to 11 kg); is installed in the OPGW.

G. Antitwisting Wire Rope

An ant twisting wire rope with rated tensile strength of 5.390 daN and weight 0,295 kg/m is used.

H. Puller and Tensioner (Fig. 3, 8 e 9)

Cable tensioning, pulling and regulating equipment includes the puller for the cable pulling and the tensioner which receives the OPGW reel, presents the following characteristics:

- Tension load: 2,000 daN;
- Speed variation: 0 to 4.2 km/h;
- Dynamometer and measurer of the cable length;
- Two drums with 5 grooves, Ø1,500 mm or Ø660 mm;
- Diesel: 24 or 35 HP, air or water cooled;
- Weight: 1,700 or 1,400 kg.

Note: Despite having different functions, the puller and the tensioner may present the same characteristics.



Fig. 5 - Curve Pulley Block



Fig. 6 - Curve Pulley Block Application

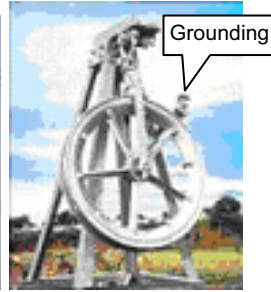


Fig. 7 - Single Pulley Block



Fig. 8 - Puller



Fig. 9 - Tensioner

IV. WORK TEAM

A. Team Formation

The presence of an experienced electrician is fundamental in the OPGW stringing team. This professional must necessarily have worked with energized circuits of transmission lines. Aptitudes such as ability, attention and agility are also paramount: electricians showing a low level of attention are placed away from risky tasks.

An OPGW stringing team comprises at most 60 people distributed into several crews, as described below. The basic composition of a team is shown in Table I.

1) Stringing crews

Normally, there are three stringing crews, broken into shifts. The aramid rope stringing is made by the first crew, the pulling and laying of OPGW is with the second crew and the third takes away the rope and the pulley blocks, while the first moves onto the next OPGW reel stringing, and so on.

2) Leveling and clamping crew:

In charge of stringing the OPGW, dead-end clamping and fixing the OPGW on the towers.

TABLE I

AVERAGE COMPOSITION OF OPGW CREWS (BASIC TEAM WITH 56 PEOPLE)

CREWS				
(1) Stringing	(2) Leveling	(3) Pulling & Tensioning	(4) Optical Splicing	(5) Supervision and Support
1 Field Works person in charge 4 Assemblers 3 Assistants 1 Driver	1 Field Works person in charge 2 Assembler 2 Levelers 6 Assistants 2 Drivers	2 Operators 2 Assistants 1 Derrick Driver 1 Tractor driver	1 Splicing technician 1 Assistant	1 Supervisor 1 General Field Works person in charge 1 Security technician 1 Administrator 1 Storekeeper 1 Site guard 2 Field guard
N° OF PEOPLE				
3x9	13	6	2	8

3) Team of equipment operators:

Operate the following machines: puller, tensioner, derrick and tractor to open accesses.

4) Optical Splicing Team:

Makes the splicing of the optical fibers in the splicing boxes of each reel length.

5) Supervision and support team:

Supervisor plans team's activities and coordinates all services. The general field works person in charge orients and follows stringing services and the safety technician inspects tasks.

B. Tool Quantity

The quantity of tools and amount of special equipment to compose an OPGW stringing team with energized line is presented in Table II.

C. Safety

Safety is paramount in the Carrier Method and every task is performed after a thorough risk analysis.

TABLE II

HARDWARE NECESSARY FOR ONE STANDARD TEAM OF OPGW STRINGING

Item	Tools and Equipment	Unit.	Qtt.
1	Self-propelled carrier	set	3 ¹
2	Aramid wire rope	m	2x6.000
3	Double vertical pulley	pc ³	2x250
4	Pulley for angle (banana)	pc	2x6
5	Single pulley block (diameter of 650 and 1,000 mm)	pc	2x(14+4)
6	Antitwisting device	pc	2x2
7	Ground wire ant-torsion pilot steel cable	m	4x1.000
8	Puller	set	1 ²
9	Tensioner	set	1 ²

Notes: 1 – One self-propelled carrier is spare.

2 – When access to tower is difficult, two sets of puller and tensioner can be used.

3 – pc = piece.

The following safety measures are taken:

- Grounding of all equipment: o puller and tensioner must be positioned on a metallic grounding mesh for voltage equalization.
- Grounding are made in the existing ground wire and OPGW using sliding devices installed in the single pulley block (Figure 7), tensioner (Figure 9) and puller.
- Utilization of proven quality tools. No imitations or experimental tooling is allowed.

A factor greatly hindering security is rain. No stringing takes place when the rain is light, or when relative humidity of the air is too high.

Individual protection equipment deserves special attention. Basically, the following type of equipment is used: insulated gloves, insulated sleeves, helmets and goggles. Conductive clothes and boots are worn in structure with high electromagnetic induction, particularly at 440, 500 and 750 kV [1].

Another important security measure regards the compliance with regulating standards of medicine and labor security, usually issued by the Ministries of Labor. They are followed strictly and usually encompass:

- 1) Standards for previous inspection and service orders;
- 2) Standard for itinerary and programming of the region's existing human resources, such as: hospitals, fire departments, police departments and forestall services
- 3) Standard for the constitution and regulation of internal commissions for accident prevention;
- 4) Standard for individual protection equipment;
- 5) Standard for medical examinations;
- 6) Standard for environmental risks;
- 7) Standard for electricity services;
- 8) Standard for cargo transportation and shifting.

It shall be emphasized that the work of OPGW stringing is only initiated after the evaluation of the local conditions and the complexity of the services.

D. Training

Training is one of the main parts of the Carrier Method. All members of the team that installed the OPGW participate in previous training to the Carrier Method.

From time to time recycling takes place. Additionally, technical auditing by independent experts occurs during task performances to assess incurred vices and risks.

Training is established in two phases:

1) Theoretical training

First aid, task sequence, procedures regarding climbing towers and moving about towers, methodologies to draw up materials, making of knots in ropes, height tasks, security distances, drawing and machine speed.

2) Practical training

Methodology simulation using de-energized lines and real application (energized line), in low speed.

One of the greatest concerns of the method regards human safety so the training emphasizes this aspect on a constant basis. One of the most important points discussed in the method is tower climbing, due to induced voltage, particularly in 345 kV and above. Climbing takes place in pre-determined locations in the tower. It is worth highlighting that 80% of the services are conducted at the top of the towers, where conductors are energized.

The method does not admit tools falling from the top of the towers.

Another crucial factor concerns the integration with the methods and practices of the clients. Only after a previous assessment has been made of regional characteristics, access maps, types of towers and their mechanical loading can the methodology be adapted to each case and type of line.

V. INSTALLATIONS

A. Transmission Lines

Between 2001 and 2006, was installed in Brazil 4,998 km of OPGW using the Carrier Method in energized OHTL, in voltages from 69 kV to 500 kV [2].

Over these six years, approximately 1,050 coils were launched.

Table III briefly lists clients and OPGW cables installed. The table enclosed presents more details regarding castings, including one for an ADSS cable and another for the replacement of GW, at 750 kV.

During several stringing, services included the installation design, the supply of the OPGW and its installation.

Figures 10 to 14 show a few OHTL where OPGW cables were stringing through the Carrier Method. The diversity in the OHTL lines can be verifies, as well as the numerous models of structures (delta, racket and pyramid).

TABLE III
INSTALLATION OF OPGW WITH ENERGIZED LINES
(TOTAL OF 4,998 KM AND 1,049 REELS)

Year	Transmission Company	OHTL Voltage	Quantity km	OPGW Fiber No.
2001 2002 2003	CHESF	230 kV 500 kV	319	24 36
2002 2003 2004 2005	CEEE	230 kV	283	24 36
2003	COPEL	230 kV	34	36
2004 2005	ELETRONORTE	230 kV 500 kV	1.264	36 72
2004 2005 2006	FURNAS	230 kV 345 kV	321	12 24
2004 2005	CTEEP	138 kV 230 kV 345 kV 440 kV	729	12
2006	EMBRATEL	69 kV 230 kV 345 kV	2.048	24



Fig. 10 - CHESF's 500 kV OHTL, Paulo Afonso - Xingó (2001)



Fig. 11 - ELETRONORTE's 230 kV OHTL, V. Conde-Sta. Maria (2004)



Fig. 12 - ELETRONORTE's 500 kV OHTL, Tucuruí-V. Conde (2004)



Fig. 13 - ELETRONORTE's OHTL 500 kV, Imperatriz-Tucuruí (2004)



Fig. 14 - CTEEP's 440 kV OHTL, Bauru-Embu (2005)

B. OPGW Characteristics

The main characteristics of OPGW installed are: [2]:

- Sectional area: from 105 to 150 mm²;
- OPGW cable diameter: from 13.8 to 16.3 mm;
- Tensile strength: from 9,209 to 12,900 kgf; and
- Weight: from 623 to 896kgf/km.

The OPGW recommended for installation in energized transmission lines using the Carrier Method is the double layer cable (Figure 15) because it is not necessary to use an ant twisting device during installation works, keeping the original distance between the ground wire and the phases conductors. The ant twisting device has a length of approximately 1.30m, which limits the working distance between the ground wire and the phase cables.

C. OHTL Particularities

The stringing of OPGW cable with energized lines can be made at any voltage or type tower.

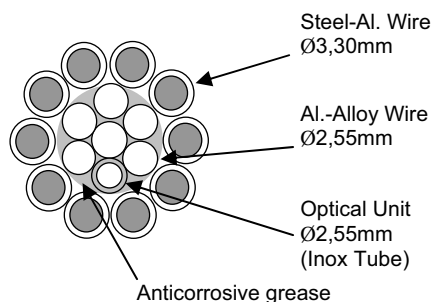


Fig. 15 - Double Layer OPGW from Fujikura, 12 OF, 115 mm² (CTEEP)

The main metallic structures of OHTL where OPGW were installed and their mainly characteristics are:

1) Delta tower (structure)

For examples: OHTL's 500 kV Paulo Afonso – Xingo (CHESF company) with 55km OPGW length (Figure 10), Tucuruí - Vila do Conde, ELETRONORTE with 273 km OPGW length (Figure 12), and some transmission lines 440kV of CTCEP company, likes Bauru - Embu Guaçu, with 85 km OPGW length.

2) Racquet tower

Example: OHTL's 500 kV Imperatriz - Tucuruí, from ELETRONORTE company, with 413 km OPGW length. This type of structure did not require the replacement of the ground wire, but rather the installation of OPGW at the side of the structure, as seen in Figure 13 (left side), with energized phases.

3) Pyramid Tower – double circuit

One such example is OHTL's 230 kV Vila do Conde - Sta Maria, from ELETRONORTE, 167 km length (Figure 16). The replacement of the GW by the OPGW was very careful because the cable stayed on the phases and on the same alignment. The Carrier Method has the advantage of the least "clearance" between cables.

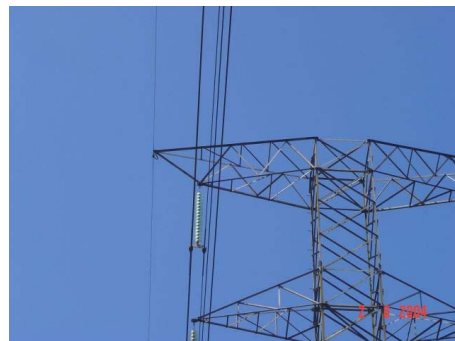


Fig. 16 - ELETRONORTE's 230 kV OHTL, V. Conde-Sta. Maria (2004)

Another example of pyramid tower is the TL 440 kV Cabreuva - Embu, from CTCEP Company, 77 km length (Figure 14). Because CTCEP's 440 kV towers have a different design configuration than the others, some precautions were deemed necessary to avoid mechanical damage to the angle brackets of the tower (extension in the structure for fixing the ground wire).

VI. PRODUCTIVITY

Conductors Clearance, tower types, lines angles, physical state of the metallic structures and ground wire, soil topography, accesses ways, communication system, training, electricians experience and mainly the adopted method are factors influencing the productivity of OPGW stringing.

A previous analysis of the line precedes the OPGW stringing planning, in which the factors influencing productivity are observed.

The average productivity achieved in OPGW stringing through traditional methods with de-energized lines is 60 to 70 km/month. Early methods developed for OPGW stringing with energized lines presented a productivity of 25 to 30 km/month.

Following a long experience, described in the above-mentioned item IV, the average productivity that has been achieved through the Carrier Method is 60 km/month/shift or the stringing of reels of app. 5 km, per week. This productivity is achieved with a standard team of around 60 people. In the presence of favorable factors, a total of 5 reels are stringing per week, as was the case in parts of OHTL of ELETRONORTE Company.

VII. CONCLUSIONS

The "Carrier Method" has been used for more than 12 years in many countries all the world. It was developed for Brazilian overhead transmission lines and demonstrated total safety in the OPGW installations on energized lines.

In Brazil, it has already stringed approximately 5,000 km of OPGW, with energized lines, in the period of 2001/2006, in lines ranging from 69 kV to 500 kV, with no accidents, as verified in the stringing work.

The average productivity attained in the stringing was 60 km/month/shift (average 3 reels per working week), with a team of approximately 60 people. This productivity is practically the same as that obtained through conventional methods in de-energized lines.

The successful experience in the six last years using the “Carrier Method” in Brazil makes it a valuable tool to be used in any country, particularly in Latin America, whose electrical system resembles the Brazilian.

The Carrier Method can also be used for inspecting the GW of OHTL, for replacement or maintenance of damaged parts of cable. That was done in a 750 kV line in FURNAS (see enclosed Table 4).

The practice and experience acquired in numerous stringing services allowed verifying that productivity varies not only according to type of tower, voltage, transmission line length, conditions of structure loading and distance from ground wire to phase conductor, but also according to the type of region (access, topography, geographic accidents). Those factors are taken into consideration when defining the costs of services, which vary according to type of tower and line voltage.

Nowadays, the “Carrier” is deemed as a proven and widely accepted method by the Transmission Companies.

VIII. REFERENCES

Papers from Conference Proceedings:

- [1] “Technology and Construction Works for OPGW Installation in Alive-Line Transmission Line”, IEEE’03 T&D Conference and Exposition, Dallas, USA, Sep.2003.
- [2] “Lançamentos de OPGW com Circuitos Energizados em Linhas de Transmissão – Metodologia Consagrada”, SNPTEE – Curitiba - PR, BRASIL, Out.2005.

IX. BIOGRAPHIES

Fumitaka Nishimura is a member of IEEE. He received his BSEE, in 1973 and the MSEE, in 1977 from USP - São Paulo University, Brazil. He obtained his doctor degree in 1988, in Power System, from USP. He was teacher at USP from 1976 up to 2003. He worked for Pirelli, Alcoa and Wirex, in Brazil, and currently, he is General Director of *ProCable Energy and Telecommunications Ltda*, Brazil. He has published and presented several papers at IEEE and CIRED Conferences and magazines.

Maurício R. Soares is a member of IEEE. He received his BSEE from Minas Gerais Federal University, Brazil (1973) and finished post-graduate studies in Power Systems and Distribution Engineering (1978 and 1980, respectively).

Mr. Soares joined *CEMIG – Companhia Energética de Minas Gerais*, Brazil, in 1974, worked then for 24 years, was Manager at the Distribution Engineering Department and currently, he is Consultant Engineer. He has published and presented several papers at IEEE and CIRED Conferences and magazines.

Liliane D. Cicarelli is a member of IEEE. She received her BSEE, in 1986 and the MSEE in Power Systems, in 1992, from USP - São Paulo University, Brazil. She worked for Pirelli, Alcoa and Wirex, in Brazil, and currently she is Financial Director of *Procable Energia e Telecomunicações Ltda*, Brazil. She has published and presented several papers at IEEE and CIRED Conferences and magazines.

Ruby Rudy Arellano is an electrical engineer from the Catholic University at Petrópolis-RJ Brazil (1991), with a MSEE from the Politechnical School, USP-SP Brazil (1997). She rendered consultancy services to *Alcoa do Brasil (1193-1996)* and *CEGELEC Engineering of Brazil (1997)*. Worked for the Power Transmission company of Panama – ETESA (1998-1999), Distribution company *EDEMET- EDECHI- Unión Fenosa* Panama (1999-2001) and *Wirex Cable S.A* Brazil (2201-2004). Currently works as an Application Engineer at *Procable Energia e Telecomunicações*.

-----<<<>>>-----

TABLE 4 – INSTALLATION OF CABLE IN ENERGIZED TRANSMISSION LINES
(TOTAL 5,134 KM AND 1,099 REELS)

Year	Customer	Transmission Line	Voltage (kV)	Quantity (km)	Reels ° Quantity.	OPGW Section (mm ²)	OPGW Fiber No.
2001	CHESF	TL Paulo Afonso IV - Xingo TL Pituaçu - Matatu	7	55 9	10 2	110	24
2001/2002	CHESF	TL Xingó - Messias	500	230	40	110	24
2002	CEEE	TL Caxias Esul - Taquara	230	67	17	111	36
2003	COPEL	TL Curitiba - Ponta Grossa	230	34	7	119	36
2003	CHESF	TL Paulo Afonso IV - Luiz Gonzaga - - Messias - Quixadá - Fortaleza II	230	25	6	111	36
2003/2004	CEEE	4 TL's	230	81	21	ADSS ¹	36
2004	ELETRONORTE	TL Imperatriz - Marabá - Tucuruí	500	353 60	77 13	105 ² 122 ²	36 72
2004	ELETRONORTE	TL Tucuruí - Vila do Conde	500	273	64	105	36
2004	ELETRONORTE	TL Vila do Conde - Guamá TL Guamá - Utinga TL Utinga - Santa Maria	230 230 230	51 20 96	11 4 21	105	36
2004	FURNAS	TL Marimondo - P. Colômbia TL Itaberá - Tijuco Preto	345 750	79 55	16 29	120 88,9 ³	12 G.W. ³
2005	FURNAS	TL Itumbiara - Rio Verde	230	209	40	120	24
2004/2005	CTEEP	Several TL's (total of 24 TL)	138 230 345 440	729	179	115 e 150	12
2005	CEEE	6 TL's	230	216	44	111	24
2005	ELETRONORTE	TL Coxito – Rondonópolis TL Rondonópolis - Barra Peixe	230	189 222	37 43	105	36
2006	FURNAS	TL Areinha - Vitória	345	33	7	120	24
2006	EMBRATEL	Rota Porto Velho - Brasília (13 TL's)	69 230 345	2.048	410	105	24

Notes: 1 – Stringing of ADSS cable in alive line (Carrier Method), without replacement of ground wire.

2 – Stringing of OPGW cable (Fig. 13), without replacement of ground wire.

3 – Replacement of ground wire in alive line (Carrier Method), without installation of OPGW.