# THE CHALLENGE OF IMPLEMENTING A NEW UNDERGROUND LINE IN A CROWDED CITY

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## *ABSTRACT*

*This paper aims to show the experience aquired and the results achieved during the implementation of the design of the RSE Juscelino Kubitscheck 138 kV underground distribution line in the São Paulo city*

*It shows the main data of the executive engineering project, the dificulties and solutions found during the construction and the methodology applied to the project management.*

*The paper shows the results achieved and the conclusions and recommendations to the application in other similar projects in AES Eletropaulo or other distribution utilities.*

## INTRODUCTION

The demand growing and the concentration of loads with the fast verticalization of the buildings in the vicinity of the Itaim Bibi and Vila Olívia neighborhoods, in São Paulo, generated the necessity of reinforcement and extension of the distribution facilities of AES Eletropaulo in this region.

After the technical and economical feasibility studies the best alternative was chosen. It was the construction of a new substation 138/13.8 kV, a feeding line in 138 kV and distribution circuits in 13.8 kV.

The unique feasible option to the feeding line was the underground solution due to the high demographic density and the occupation of the land in the region.

The chaotic occupation of the subsoil, the geotechnical characteristic of the soil, the water table level and the traffic of vehicles created numberless obstacles to the implementation of the line. The overcoming of all these obstacles is described in this paper that shows the engineering solutions found and the good results achieved.

## ENGINEERING SOLUTIONS USED IN THE PROJECT

The feeding line designed has 3,280 m length, 2 triphasic circuits, voltage of 138 kV, initially operating in 88 kV, and 110 MVA of capacity per circuit.

The chosen constructive type in the project was open trench, 0.80 m width and 2.60 m deep. The crossings of avenues and big interferences were performed through horizontal directional drilling – HDD, with 10 m maximum deep.

The figure 1 shows the section of the trench and the section of the HDD.

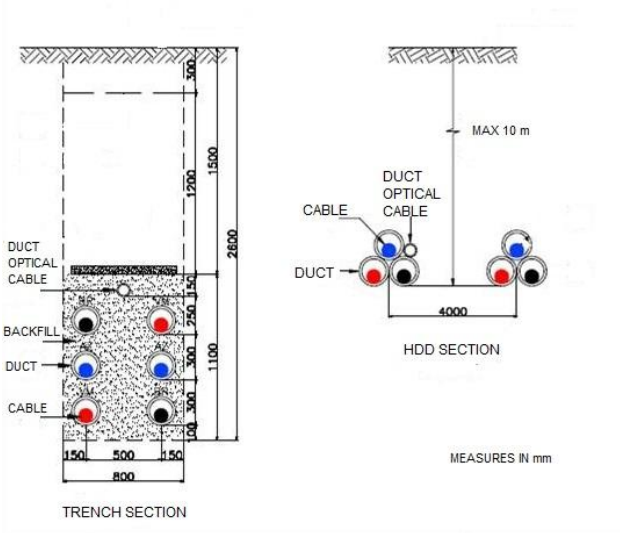


Figure 1: Section of the trench and the HDD

The cables were installed into corrugated ducts filled with bentonite and enveloped with backfill thermally stabilized.

The optimal gauge of the cable was achieved with the earthing of the metallic sheath in cross bonding system, with sections of approximately 550m between joints.

The dimensioning was according to the methodology of Standards IEC 60287 [1] and 60853 [2], and resulted in a cable insulated in cross linked polyethylene – XLPE, with aluminum conductor of cross section of 1,200 $mm^2$ to attend the nominal current capacity in normal regimen of operation.

It was used 30 sectionalized normal joints and 12 external terminations with polymeric insulator of glass fiber and silicon.

One optical fiber cable was installed along of the line connecting the control and protection systems between the two substations. The type of the cable is duct & directly buried – DDR – with anti rodents external sheath, protection against fungi and bacteria, temperature of operation from -20° C to +65° C, with fibers with

acrylate coat inside loose-tube gel filled, gathered around a dielectric central element. It was manufactured according the Brazilian Standard ABNT NBR 14733 [3] and it has 36 single mode fibers, with diameters of 9/125 µm core and shell, to operate in the range 1310/1550 nm with attenuation of 1310 nm ≤ 0,35 dB/km e 1550 nm ≤ 0,25 dB/km.

One innovation introduced in this project, that allows a better reliability and a better exploitation of the capacity of current of the power cable was the installation of a distributed temperature monitoring system – DTS with software to calculate the real time thermal rating – RTTR. The system consists of two multi-mode optical fiber pairs, internally inserted in the cover of the conductor cable, a measuring and data collection equipment installed in the substation Juscelino Kubitschek, and software for the estimation of the current in real time.

For its construction were obtained authorizations from several departments of the São Paulo City hall, and the agreement of the water and sewage utility (who built a new sewer collector tunnel in the same region), and permits to transport of the land resulting from the excavation of the trenches.

It was also necessary environmental licensing, which among other requirements requested compliance with the limits of magnetic field emission of Ordinance 80 of the Green and Environmental Department of the city hall. This limit is 3 µT on the facade of the buildings in front of the line.

The city hall of São Paulo only allowed the civil works and the cable installation at night, between 10 pm and 5 am, because the line was inside a region of heavy traffic. After the works during the night period the lanes of the streets must be liberated to traffic during the day, with the removal of the signalization and fall protection fences. During the day it was used steel plates to close the trenches opened during the night.

The box of joints could be kept opened during the day. This allowed the assembly of these accessories during the day. Another important constraint in this project was its localization into a region of restriction to the traffic of trucks and machines.

## ASPECTS OF THE CONSTRUCTION OF THE LINE AND ENGINEERING SOLUTIONS DURING THE WORKS

Different types of soil was found along the line route, from the source substation ETD Monções, situated in the confluence of Bandeirantes Avenue and Berrini Avenue, up to the new substation ETD Juscelino Kubitschek, built in the corner of São Gabriel Avenue and Antônio Joaquim de Moura Avenue.

The soil of higher incidence was classified as alluvial and organic – dark turf and highly compressible, unstable and difficult to handle, and with characteristic smell.

The water table level in the majority of the work was 1.50 m depth and above the trench bottom situated at 2.60 m.

These characteristics of the terrain, combined with the various interventions of other utilities in the place, complicated the excavation and construction of the ducts banks due to the instability of the walls of the trenches and the presence of water in a large extension of the line route.

Given the above conditions the applied solution was to open trenches with mini excavator, and continuous shoring along the excavations, carried out partially – open stretches with a length of approximately 30 m. Due to the low soil cohesion capacity, the implementation of the activities was difficult, which reduced the productivity of the work.

The work was done in open trenches in more than 95% of its total extension, according to the design. In some places, due to the high number of interferences, the excavations initially planned to be mechanized, were done manually, mainly in the proximity of the underground energy nets, gas ducts and into the substations.

The excavation tried to keep the profile and the depth of the designed trenches, but due to the interferences with the existing facilities of other utilities of public services, it was necessary the execution of duct banks with several horizontal and vertical curves, which resulted in a bigger number of lubricating passage boxes to alleviate the strength during the pulling of the cables. The figure 2 shows details of the trench shoring.

Figure 2: Trenches and Joint Boxes Shoring

In addition to open trench, the project considered the construction of stretches of the line using the horizontal directional drilling, that is a non disruptive method - NDM.

Due to the necessity of using ducts with 200 mm nominal outside diameter to allow the accommodation of cables inside, the thick of the walls of these ducts, as well as its mass per unit length, it was required the execution of large diameter holes and the employment of large drilling machines.

Two holes were performed by the NDM method, one for each circuit, and three ducts was pulled at the same time.

During the construction it was necessary to increase the number of stretches of NDM, replacing the sections of trenches initially projected, due to interferences not registered during the field survey that totally obstructed the passage of cables in the designed depth. In these sections the cables were installed at depths greater than 4 meters.

One innovation used in this construction was the foundation for the external terminals. Precast concrete bases were used instead of using the traditional foundation molded "in loco". This solution reduced the number of man hours on the work front and the lead time.

Another new solution employed during the construction were the precast concrete structures for shelter the link boxes of cross bonding system, which at the sites of the joints 1 and 2 were installed on the road, since there was no enough space on the sidewalk due to interferences not registered. These structures replaced the masonry boxes initially designed to be built on the sidewalks, had internal dimensions of 1.70 m X 1.70 m and depths of 1.30 m and 2.00 m, and were designed to support the weight of vehicles according with the types specified in the Brazilian standards.

Several factors contributed to difficult the work, requiring specific solutions of engineering and management during the construction. The following situations and their solutions can be mentioned:

- ✓ The low local soil reuse rate for backfill, the night period allowed for the execution of the trenches, the approved disposal sites for the excavated soil that do not work at night, and the truck traffic restriction on region during the day, prevented the transport of the inert material directly from the work place to the local of final disposal of waste. The logistics solution for this situation was the night transport of the excavated material from the jobsite to a temporary storage place, and further transport to the final disposal places during the day.
- ✓ The soil of the site was not appropriate for backfill, and there was no availability of good soil for this purpose due to the rainy season, since the soils from conventional deposits were saturated. The solution was to use material from recycled concrete as an alternative. This material has high compression rate and reasonable water resistance, reducing potential settlement of the reassembled roads during the rainy season.
- ✓ The period released to the works (night) had divergences with current noise emission legislation in São Paulo - "law of silence". Residents called the police to resolve the impasse numerous times, because they ignored the permission of the municipal administration for this work. The clarification of the population about the importance of the work, through pamphlets and communication actions minimized these situations.
- ✓ The work was partially located - stretch 1, 2 and 3 - into streets that had many nocturnal activities, where there were many bars, restaurants and concert halls. This situation created difficulties to keep the route of the line without vehicles parked in places where the trenches would be dug. The clients of the bars and the valet of the cars caused great inconveniences during the construction activities. The dialogue with the owners of these establishments, and the placement of signs and protection fences immediately after the beginning of the time allowed for the works reduced these occurrences
- ✓ The places of the work, in addition to daily sweeping after the end of the work, were repeatedly washed with water trucks due to the rainy season and soil characteristics in the region.
- ✓ One of the great difficulties of constructing underground lines in São Paulo is the dense and disorderly occupation of the subsoil. There is no specific law for this purpose, and some companies build their networks in a disorderly way and sometimes without design or legal authorization. Existing records of facilities are unreliable, and in many cases there is no revision "as built" of the projects, which complicates the location of excavations and can change the profile and positioning of the project during the construction. The solution to reduce this situation was survey the interferences "in loco", both before the design and during the work, using different methodologies: grounding penetrating radar - GPR, visual inspection, electromagnetic inspection, and pre-excavation at certain points. But even with all these resources, we could not avoid unforeseen cases and the need for changes in trenches due to interference not previously detected in various places.

Despite all these difficulties the work was completed on time and within the margins in the budget.

## PROJECT MANAGEMENT

The implementation of RSE Juscelino Kubitschek presented great challenges to professionals who integrated the team responsible for the enterprise at different stages of the project. During all stages: feasibility studies, definitions of the budget of the work, studies and preparation of the executive project, obtainment of licenses from the competent authorities

and the effective execution of the work, particular situations were found, which required the experience of professionals who composed the team and forced the team to adopt innovative technical solutions for their management.

Front of the scenario composed of adverse situations in the environment of the underground line installation, limited time for finish the construction and the need to monitor systematically the budget of the project, the management team adopted a project management system based on the precepts of the PMBOK - Project Management Body of Knowledge, reference guide for the PMI - Project Management Institute. Following are some of the tools used and the results obtained during the project management.

## Definition of key success factors

To guide the management process, the first step was to define the key factors to the sucess of the project. Considering the variables involved, the project team chose four key factors to the success of the enterprise. They were: safety, quality, time and budget.

Based on these drivers, tools and methodologies were defined to manage the progress of work and enable the achievement of these key factors and ensure project success.

## Risk management

To map and manage the risks of the project, the team created a spreadsheet that related the probability of each risk occurs and the impact on the project if it happens. Notes were assigned to the probability and to the impact and the products of these notes generate an indicator of severity, which assisted in the strategy to be adopted by the manager in relation to the risk.

Along the RSE Juscelino Kubitschek project were identified some risks that could impact harshly the project and jeopardize the achievement of the success key factors. Among them, there was the risk of suspension of the project due to possible lawsuits by residents and businesses in the region, motivated by inconveniences caused by the works. To mitigate this risk, the project team decided to develop a communication plan with the community of neighborhoods near the route of the underground line, informing the benefits of the project for the region and the measures taken to minimize any inconvenience during the project execution. This plan included the realization of meetings with the community leaders (neighborhood association, trade associations, etc.), delivery of flyers to the residents and businesses in the region and training of employees of the relationship centers of the utility on information related to the project.

## Time management

The Juscelino Kubitschek complex comprised beyond the 138 kV underground line, the construction of a new substation with installed capacity of 120MVA, a transition substation overhead to underground line and 12 distribution circuits of 13.8kV. Because of the need to achieve the date set by government agencies to the entry into operation of the facilities, included in the supply plan for the FIFA World Cup in 2014, the project team faced a reduced period for development of all phases of the project. The time available between the feasibility studies and the completion of the constructions was 40 months, including obtaining all licenses and authorizations from government agencies, preparation of detailed design, procurement of services and execution of the works. In addition, to enable that all the works of JK complex were ready within the proposed date by government, it was necessary to promote the coordination of all projects, to not delay the entire complex.

In these circumstances, the project team defined a general chronogram to the Juscelino Kubitschek Complex. This chronogram was related to the detailed chronogram of each work of the Complex.

For the underground line project, the team determined that the chronogram would be accompanied weekly to ensure that the original plan was being followed and that any problems encountered during the development of the work would be treated in time to avoid delaying the project. This monitoring was performed during weekly meetings with the entire project team. The chosen tool for chronogram management was the Microsoft Project.

The result of the chronogram management was the anticipation of a month of completion of the work, originally scheduled to be completed by May 30, 2014.

## Budget management

To manage the budget of the work, were used the SAP R3 tools that organize the financial resources of the project and its disbursements through a structure consisting of investment requests (a kind of cost center where the budget is available). Disbursements made in the project were appropriated in specific cost elements according to the type of payment, for example, materials, services, payment of taxes and others.

To facilitate the user access to information and data analysis, the SAP R3 tool provides reports and interfaces with the possibility of customization of fields, filter insertion and exportation of information to Microsoft Excel. The result of this management was the completion of the project with costs only 2% higher than the budget initially foreseen.

## Safety aspects

To ensure the safety of the public and employees involved in the work of RSE Juscelino Kubitschek, the project team adopted the measures provided for in the technical specifications and document called Basic Safety Guidelines of AES Eletropaulo. In addition, were observed and respected the control measures and decisions of law. Measures were adopted primarily to signal the work sites and the traffic diversions during the activities on public roads. Figure 3 shows details of fall protection fences and signaling of the works.

Figure 3: Fall protection fence and signaling of the works

Special attention was paid to continuous shoring during construction of lines of ducts, trenches and boxes of joints to control the risk of landslide due to the low quality of the soil in the area and the depth of the designed trench.

As an example of the practices adopted by the team responsible for safety, we highlight the completion of a daily dialogue about safety with the employees, weekly lectures on issues related to safety, safety inspections and employee training.

It stands out that the work was completed without the occurrence of accidents with employees and population.

## Environmental aspects

To meet the conditions set out in the environmental installation license for obtaining the operation license and in line with the policy of respect to the environment adopted by AES Eletropaulo, the project team adopted a control plan of environmental impacts during the construction work. The plan was to deploy methods for prevention, mitigation and control of environmental impacts and monitoring on all fronts and work sites, such as emission of waste and smoke from vehicles, chemical spills, among others. In addition to training and awareness of workers, the responsible for monitoring of the plan hold weekly visits to work sites to verify compliance with the plan.

## CONCLUSIONS

The implementation of the underground line RSE Juscelino Kubitschek was successful since it was delivered on time and on budget initially planned, despite the short time and limited financial resources to achieve them. The determining factor for this success was the project management methodology based on the PMBOK, strict observation and monitoring of safety and environmental aspects, and the commitment of the entire team with the goals of the enterprise.

Other equally major factors were: the quick solution of problems and unforeseen faced during the work, and the good capacity of mobilization of the civil works contractor in terms of human resources and vehicles and equipment, which at certain moments of the work provided four to five times the average of the initial estimates to recover the chronogram and avoid delays.

A good executive project, with the prior detailed survey of interferences as done in this line, helps in mitigating risks in underground works of this type.

The collaboration with other utilities that owned facilities along the route, the dialogue with the local population and traffic surveillance authorities as well as the city hall were also of fundamental importance to avoid delays and consequent increments of spending.

It would be very desirable that the Brazilian municipalities that discipline the occupation of urban underground establish standards to organize this occupation and facilitate future underground constructions that tend to increase exponentially in the near future in Brazil.

## REFERENCES

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[3] ABNT Associação Brasileira de Norma Técnicas, NBR 14773 - Cabo óptico dielétrico protegido contra ataque de roedores para aplicação em linhas de dutos – Especificação.